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NASA Technical Paper 1383

Characterization of Large 2219 Aluminum Alloy Hand Forgings for the Space Shuttle Solid Rocket Booster

M. W. Brennecke

DECEMBER 1978

NASA

110

NASA Technical Paper 1383

Characterization of Large 2219 Aluminum Alloy Hand Forgings for the Space Shuttle Solid Rocket Booster

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National Aeronautics
and Space Administration

**Scientific and Technical
Information Office**

1978

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TECHNICAL PAPER

CHARACTERIZATION OF LARGE 2219 ALUMINUM ALLOY HAND FORGINGS FOR THE SPACE SHUTTLE SOLID ROCKET BOOSTER

INTRODUCTION

Large aluminum forgings required for the Space Shuttle are of sizes beyond the scope of existing specifications and are, therefore, in the class of "special purpose forgings." The property data available in 1974-5 for 2219-T852 forgings in thicknesses over 8 in. were meager or nonexistent. Hence, the minimum guaranteed properties provided by the forgers for thicknesses greater than 8 in. were conservatively estimated. Therefore, a material evaluation program was established by the Materials and Processes Laboratory of the George C. Marshall Space Flight Center (MSFC) when the forgings were ordered for the Solid Rocket Booster (SRB) structural components. The program plan delineated the requirements for destructively tested forgings and forging prolongations to provide basic data for material characterization and to establish minimum guaranteed properties for structural refinement and future applications.

DESCRIPTION

Objective and Approach

The objective of the program was to characterize large hand forgings of 2219-T852 aluminum and to establish minimum guuranteed mechanical properties for current and future applications.

Four types of hand forgings ordered for the Space Shuttle SRB Structures were evaluated. One to three forgings of each configuration were destructively tested to determine macrostructure, grain size, mechanical properties, stress strain curves, ductility, fracture toughness, and resistance to stress corrosion cracking. Prolongations were tensile tested on each individual forging by the forger for quality control.

The forgings ranged in thickness from 5-3/4 to 16-1/4 in., from 10-1/2 to 29-1/2 in. in width, from 33 to approximately 115-1/2 in. in length, and from 450 to 3500 lb at time of heat treatment. The two contour forgings produced by one forger for the holddown post (P/N 14A30400) and for the thrust post (P/N 14A20084) are depicted in detail with dimensions and forger test specimen layout in Figures 1 through 4 and Figures 5 through 9, respectively. Figure 7 presents a closeup view of the forward tapered segment of the thrust post. The two rectangular forgings produced by another forger are sketched showing dimensions and forger test specimen layout in Figure 10 for the splice fitting (P/N 14A30500) and in Figure 11 for the actuator support bracket (P/N 14A30905). The latter is the only forging delivered in the -T852 temper for hardware. The other three are delivered by the forger in the -T352 temper to be welded into an assembly and aged by the SRB Structures contractor, McDonnell Douglas Astronautics Company (MDAC). All segments of the original destruct forgings are aged by the forger to -T852 temper for testing.

Details of the tests to be performed by the forgers were included in the MSFC procurement specification for each of the four types of forgings, as shown by one example in Appendix A. Results of forger tests were provided to MSFC on certification sheets (illustrated in Appendix B) and by letter. Supplemental tests performed by MDAC were according to the MSFC plan incorporated in NASA Contract NAS8-31732. These results were provided periodically to MSFC on data sheets and summarized in an interim report (Reference). Results of tests from both sources as organized and evaluated at MSFC are presented herein.

Simulated hardware aging tests performed by the SRB Structures contractor (MDAC) on welded assemblies representing a 1/4 circumferential segment each of a complete forward and aft skirt aged on the fixtures and in the furnace used for full scale hardware, provided test material for comparison between forger- and user-aged material. These tests will be described in detail in a separate report; however, the properties are included here to demonstrate the difference between forger delivered -T852 temper and hardware-assembly-aged -T852 temper 2219 forgings.

Minimum mechanical properties guaranteed by the forgers in 1974-6 are given in Table 1 by thickness and SRB forging part number. The values are plotted in Figures 12, 13, and 14 for longitudinal (L), long transverse (LT), and short transverse (ST) directions, respectively.

Test Results

Results of the forger and MDAC tests on the holddown post, P/N 14A30400, are given in Tables 2 through 6 and are plotted in Figures 15, 16, and 17. Strengths decrease with increasing thickness. In the heavier gages actual values far exceed the minimum guaranteed by the forger at time of procurement (Figure 15, p. 20).

Results of the forger and MDAC tests on the thrust post, P/N 14A20084, are given in Tables 7 through 11 and are plotted in Figures 18 through 21.

Test results from the forger and MDAC tests on P/N 14A30500 are given in Tables 12, 13, and 14 and on the actuator support bracket, P/N 14A30905, in Tables 15, 16, and 17.

Forger prolongation tensile test data for the four forging configurations combined are shown in Figures 22, 23, and 24 for L, LT, and ST test directions, respectively. A condensed summary of the combined prolongation and destruct data for the four forging configurations is given in Table 18 and is plotted in Figures 25, 26, and 27 for L, LT, and ST directions, respectively. The number of specimens tested for a given location and orientation varies from 3 to 136 for a specific part number (P/N), whereas a total of 1230 tensile tests were made at ambient temperature (Figure 26, p. 31 and Table 18, p. 72-3).

Macrostructure and grain size as determined by the forgers are available at MSFC. Stress strain curves are likewise available for specimens noted in Tables 4, 9, 13 and 16.

MDAC test data on forger-aged contour material tended to be approximately 1 ksi lower than forger tests. Likewise, the MDAC 1/4 in. diameter specimens tested for stress corrosion blanks tended to show approximately 1 ksi lower tensile yield strength (TYS) than the 1/2 in. diameter specimens.

Mechanical properties varied up to 5 ksi across the 11 in. width of the 8 by 11 in. rectangular forging (Table 13). For a given location from one serial number forging to another there was a maximum variation of approximately 10 ksi for 61 parts (Table 14, p. 67).

The prolongation data for contour forgings show remarkably consistent values, whereas the destruct data for three forgings of the thrust post show considerable spread from one serial number to another particularly in the 1/4 width location in the 14 in. thick segments (Table 7). This situation limits the ultimate tensile strength (UTS) to the original guaranteed 50 ksi but permits some increase in TYS to at least 40 ksi for forger-aged material (Figure 19, p. 24).

Proposed minimum guaranteed mechanical properties for 2219-T852 hand forgings are given in Table 19 and are plotted in Figures 28, 29, and 30 for L, LT, and ST directions, respectively. These may be considered firm values for rectangular forgings of a given thickness and as guideline or tentative values for a given thickness within contour forgings.

All stress corrosion tests were satisfactory on the 66 forging specimens and the 25 reference plate specimens (Tables 4, 9, 13 and 16). Metallographic examination of corroded specimens at MSFC showed only pitting type of attack, as illustrated by microstructures exhibited in Appendix C. All K_{Ic} fracture toughness values were above the estimated minimum of 20 ksi $\sqrt{in}$. Most of the values were for the S-L direction. The limited number of valid tests in the L-S direction resulted from the specimen size being too small. A total of 89 compact tension specimens were tested at ambient temperature (Tables 4, 9, 13 and 16).

A limited number of elevated temperature tests at 200°F and 300°F (Table 13) show that strengths and fracture toughness decrease with increasing temperature. The K_{Ic} tests were invalid due to the specimen size being too small.

Destruct and prolongation tests on the thrust post and holddown post from the MDAC 1/4 skirt aging tests are included in Tables 5, 6, 10, 11, and 18 and are plotted in Figures 15, 16, 17, 21, and 23 through 27. Generally, lower strengths were developed in the simulated hardware aged by the contractor than in forgings aged by the producer. In the thinner portion (5-3/4 in. thick) of the thrust post (14A20084), properties failed to meet the minimum guaranteed by the forger in the longitudinal direction by 2 to 4 ksi (Figure 25). Further evaluation is in progress to define the problem and establish the necessary process control for hardware.

CONCLUDING REMARKS

The following conclusions are based on results of tests on 171 individual hand forgings of 4 distinct items produced by 2 forgers, tested by the forgers and also by the SRB Structures contractor — MDAC. There were a total of 1250 tensile tests, 100 fracture toughness tests, and 91 stress corrosion tests.

1. Strengths of 2219-T852 rectangular and contour forgings, weighing 450 to 3500 lb, generally equaled or exceeded the minimum values guaranteed by the forgers in 1974-5.

2. Strengths vary with forging thickness, with cross-sectional area, with forging contour, and with location within the forgings.

3. The previously guaranteed values are appropriate now for gages up through 8 in. thick when aged by the forger.

4. Increased strength guarantees are proposed for rectangular hand forgings greater than 8 in. thick supplied by the forger in the fully aged -T852 temper.

5. Caution is advised in predicting guaranteed values for either rectangular or contour forgings in any gage when aged by the user to the -T852 temper since aging conditions employed for hardware assemblies may differ appreciably from those normally employed in a producers' plant.

6. Caution is advised in predicting guaranteed values for contour forgings aged by the forger since properties may vary (a) with the contour and (b) with the process variables inherent with the specific contour.

7. Strengths guaranteed by the forger in 1976 for the contoured thrust post P/N 14A20084 are still appropriate for forger-aged material.

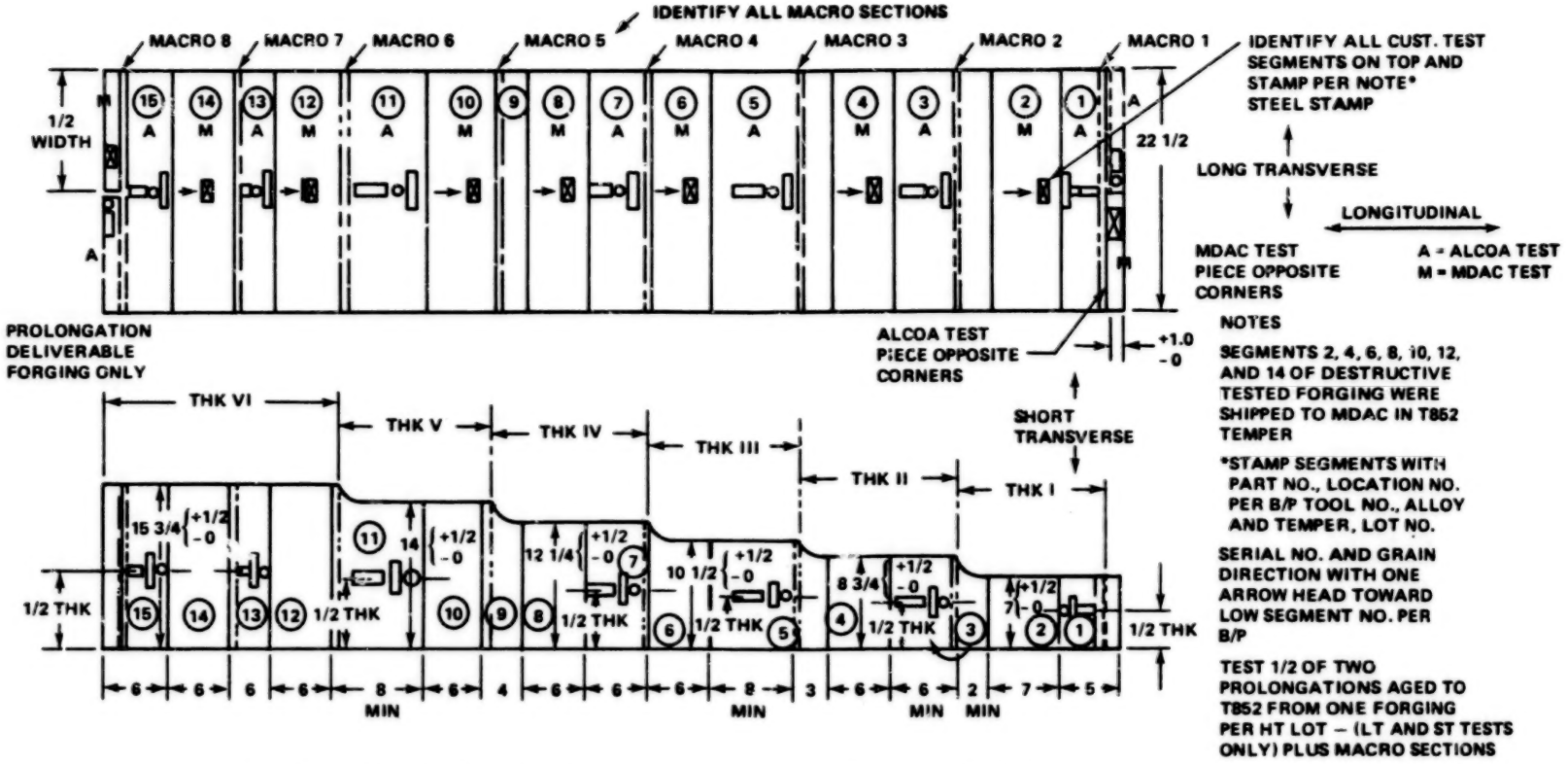
8. Strengths initially guaranteed by the forger in 1974-5 for the contoured holddown post forging P/N 14A30400 are still appropriate for forger-aged material up through 8 in. thick; however, for the 8-3/4 to 16-1/4 in. thicknesses, strengths could be upgraded, particularly tensile yield strength.

9. No stress corrosion cracking failures occurred during a 30-day exposure to 3.5 percent NaCl solution by alternate immersion of short transverse tensile specimens stressed to 75 percent of their yield strength.

10. Corrosive attack was not accelerated by stress. Losses in strength and in elongation were no greater for the forgings than for the 6 in. thick -T851 reference plate exposed simultaneously. All showed only pitting type of attack.

11. Fracture toughness K_{Ic} values of the forgings ranged from 20.72 to 35.32 ksi $\sqrt{in.}$

12. Strength and fracture toughness decreased with increasing temperature of 200 and 300°F.


IDENTIFY ALL MACRO SECTIONS
MACRO 8
MACRO 7
MACRO 6
MACRO 5
MACRO 4
MACRO 3
MACRO 2
MACRO 1
1/2 WIDTH
22 1/2
IDENTIFY ALL CUST. TEST SEGMENTS ON TOP AND STAMP PER NOTE* STEEL STAMP
LONG TRANSVERSE
LONGITUDINAL
MDAC TEST PIECE OPPOSITE CORNERS
A = ALCOA TEST
M = MDAC TEST
PROLONGATION DELIVERABLE FORGING ONLY
ALCOA TEST PIECE OPPOSITE CORNERS
+1.0 -0
SHORT TRANSVERSE
THK VI
THK V
THK IV
THK III
THK II
THK I
1/2 THK
6 6 6 6 8 6 4 6 6 6 8 3 6 6 2 7 5
MIN
NOTES
SEGMENTS 2, 4, 6, 8, 10, 12, AND 14 OF DESTRUCTIVE TESTED FORGING WERE SHIPPED TO MDAC IN T852 TEMPER
*STAMP SEGMENTS WITH PART NO., LOCATION NO. PER B/P TOOL NO., ALLOY AND TEMPER, LOT NO.
SERIAL NO. AND GRAIN DIRECTION WITH ONE ARROW HEAD TOWARD LOW SEGMENT NO. PER B/P
TEST 1/2 OF TWO PROLONGATIONS AGED TO T852 FROM ONE FORGING PER HT LOT – (LT AND ST TESTS ONLY) PLUS MACRO SECTIONS

MIN PROPS FOR 2219 Al FORGINGS AGED TO T852 TEMPER

THICKNESS	DIRECTION	TENSILE KSI	YIELD KSI	ELONG %
THK I 7"	LONGITUDINAL	62	50	6
	LONG TRANSVERSE	61	49	4
	SHORT TRANSVERSE	60	46	3
THK II 8 3/4"	LONGITUDINAL	55	43	6
	LONG TRANSVERSE	56	42	4
	SHORT TRANSVERSE	53	40	3

*FOR ALCOA TEST LAB ONLY

THICKNESS	DIRECTION	TENSILE KSI	YIELD KSI	ELONG %
THK III	LONGITUDINAL	52	39	6
THK IV	LONG TRANSVERSE	52	38	4
10 1/2" – 12 1/4"	SHORT TRANSVERSE	50	36	3
THK V	LONGITUDINAL	46	33	6
THK VI	LONG TRANSVERSE	46	32	4
14" – 16 1/4"	SHORT TRANSVERSE	44	30	3

Figure 1. Dimensions and layout for contour hand forging P/N 14A30400.

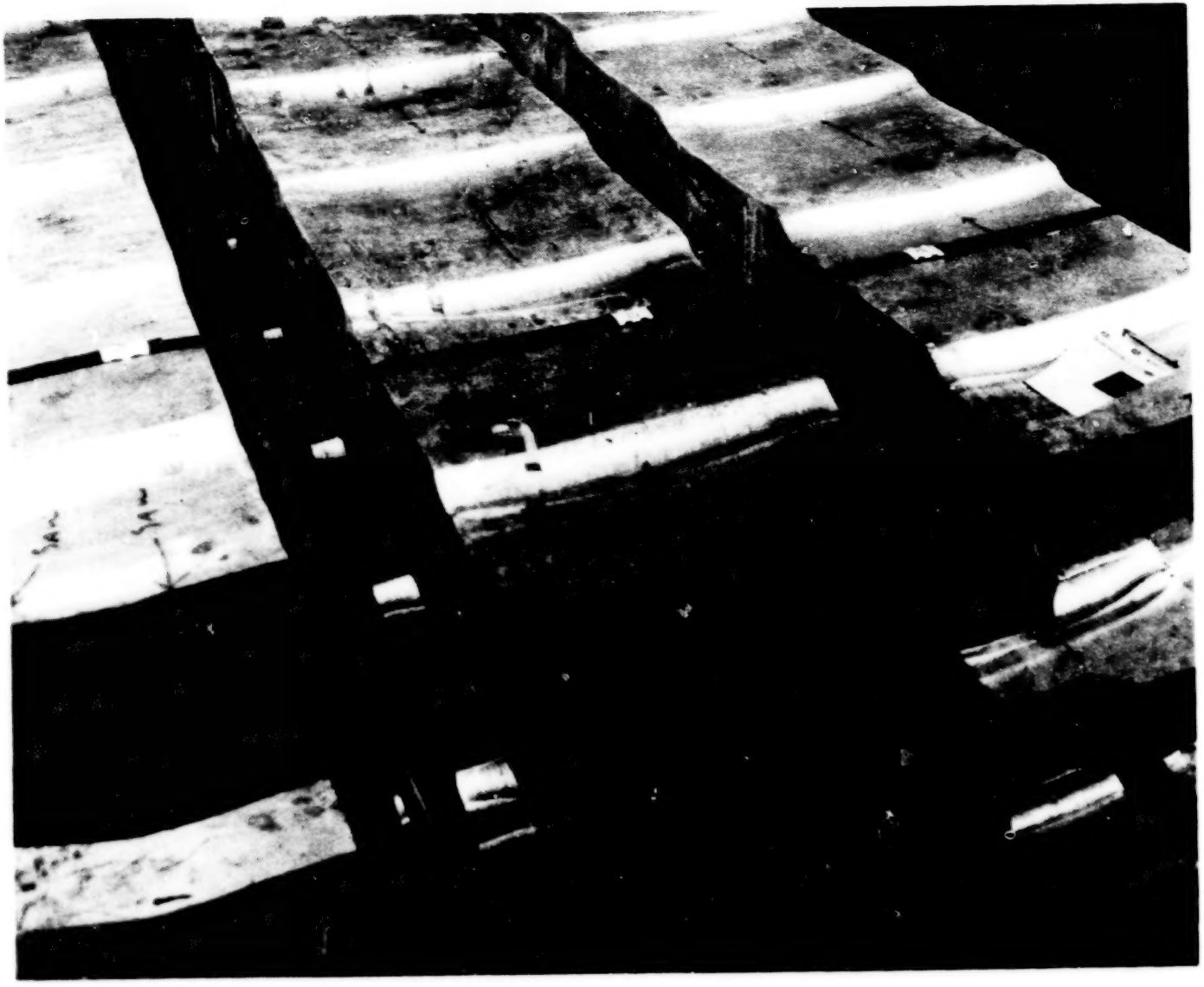


Figure 2. Contour forging P/N 14A30400 for holddown post.

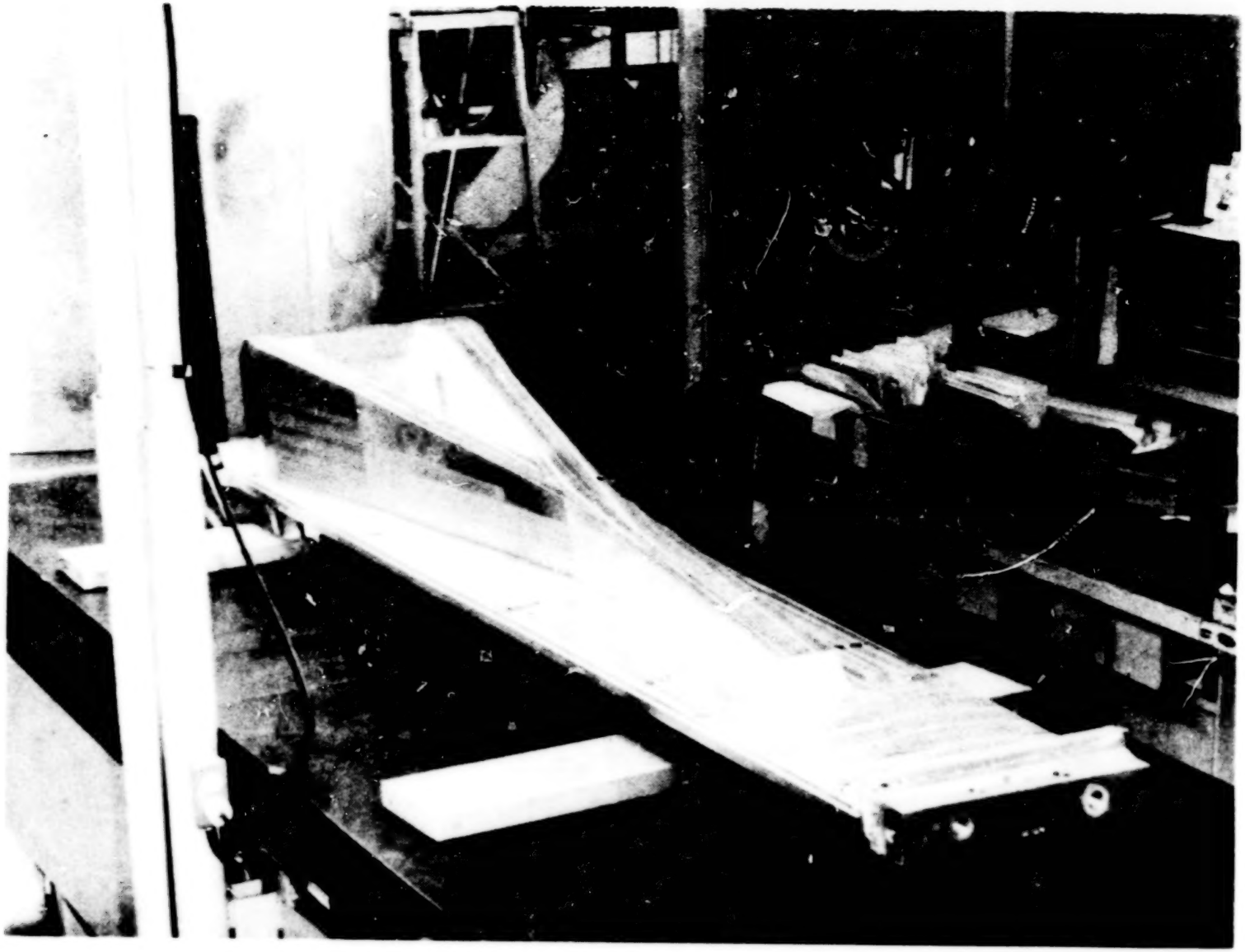


Figure 3. Aft skirt holddown post (P/N 14A30414) — machined.

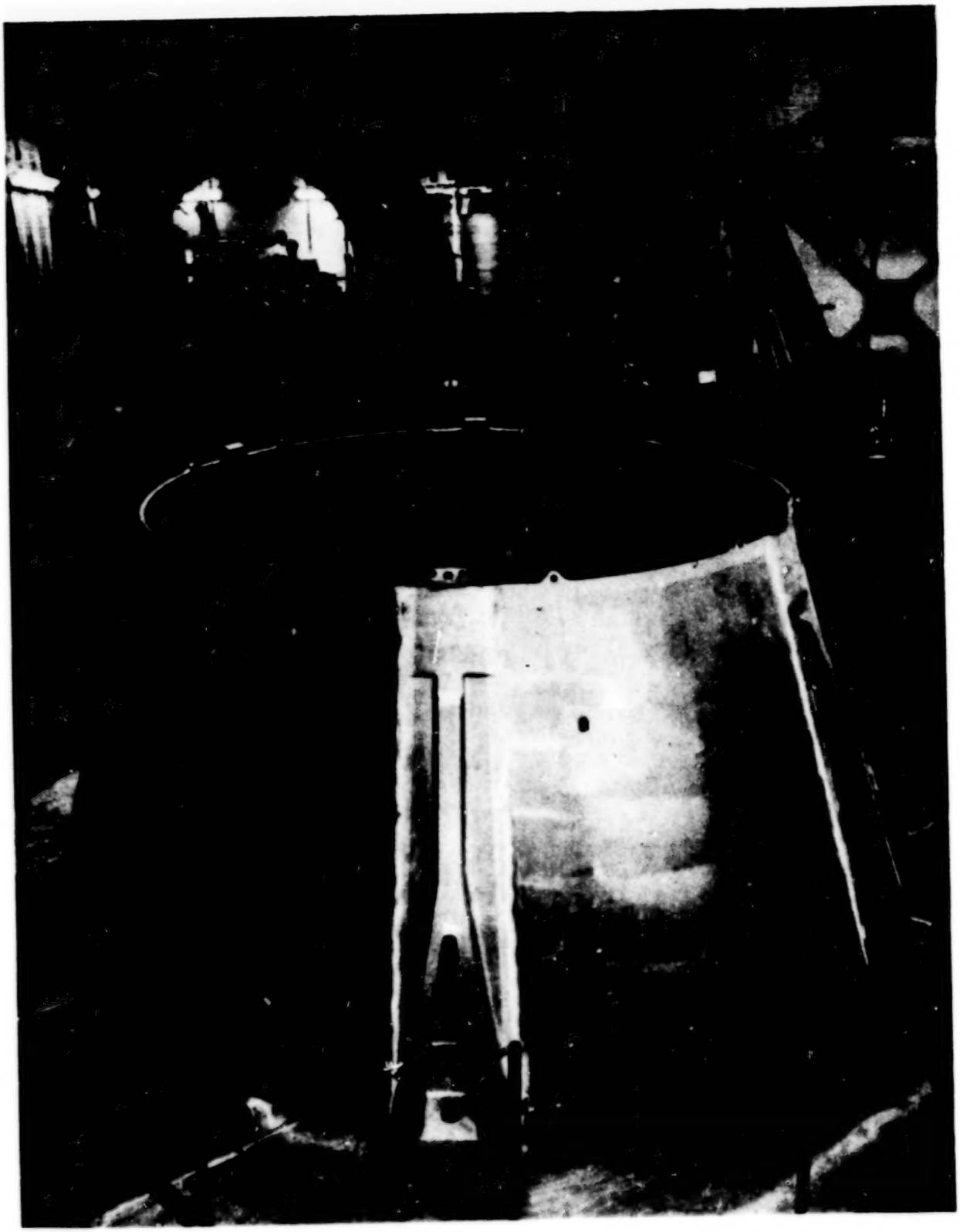
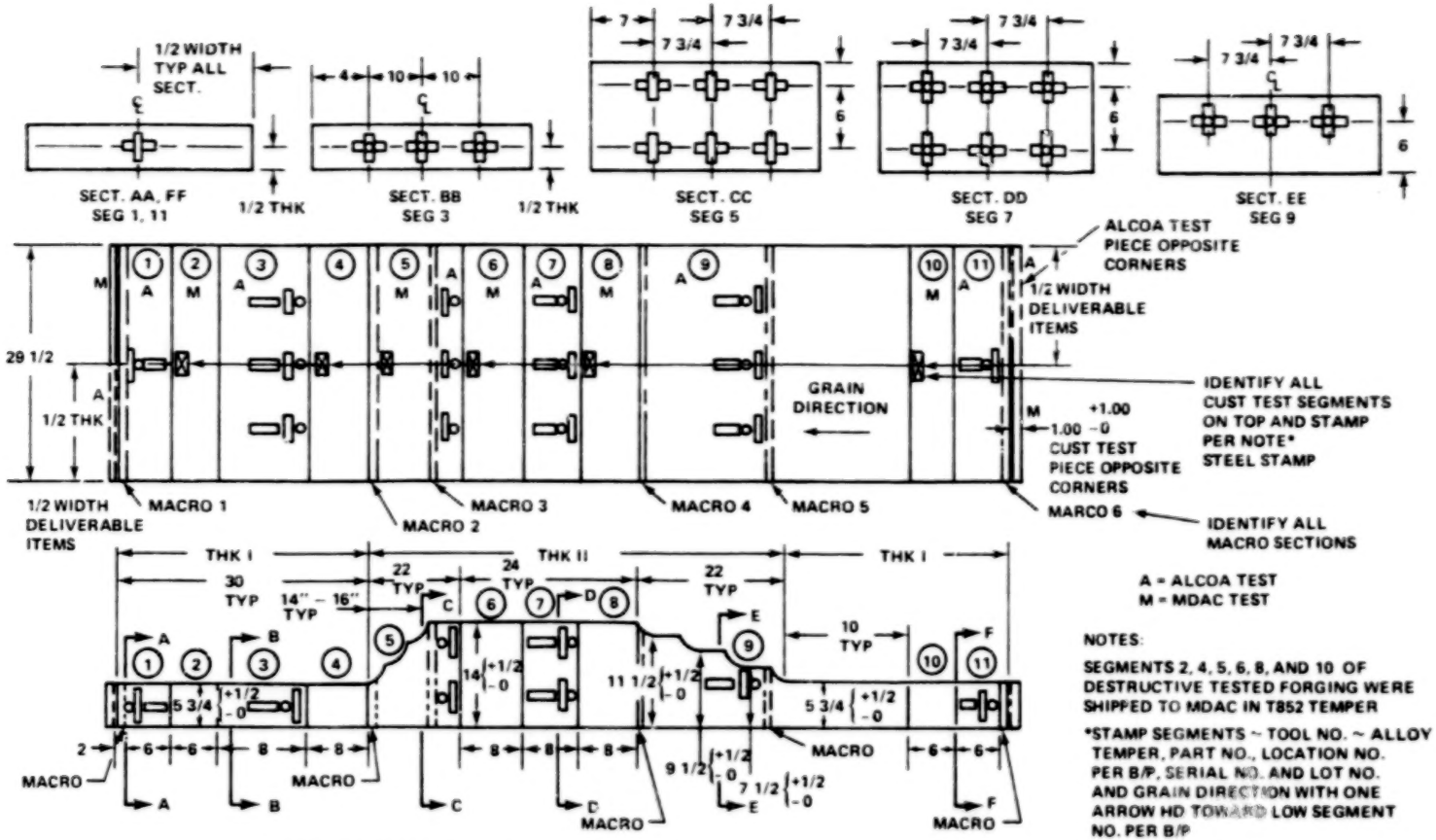


Figure 4. Aft skirt – holddown posts welded to skins.



NOTES:

SEGMENTS 2, 4, 5, 6, 8, AND 10 OF DESTRUCTIVE TESTED FORGING WERE SHIPPED TO MDAC IN T852 TEMPER

*STAMP SEGMENTS ~ TOOL NO. ~ ALLOY TEMPER, PART NO., LOCATION NO. PER B/P, SERIAL NO. AND LOT NO. AND GRAIN DIRECTION WITH ONE ARROW HD TOWARD LOW SEGMENT NO. PER B/P

TEST 1/2 OF TWO PROLONGATIONS AGED TO T852 FROM ONE FORGING PER HT LOT (LT AND ST TESTS ONLY) PLUS MACRO SECTIONS

MIN PROPERTIES FOR 2219 Al FORGINGS AGED TO T852 TEMPER

THICKNESS I 5 3/4 IN.

	TENSILE KSI	YIELD KSI	ELONG %
LONGITUDINAL	61	49	6
LONG TRANSVERSE	61	48	4
SHORT TRANSVERSE	59	45	3

THICKNESS II 7 1/2 IN. TO 14 IN.

	TENSILE KSI	YIELD KSI	ELONG %
LONGITUDINAL	50	37	6
LONG TRANSVERSE	50	36	4, 3†
SHORT TRANSVERSE	48	34	3

†SEG 6-8

Figure 5. Dimensions and layout for contour hand forging P/ N 14A20084.

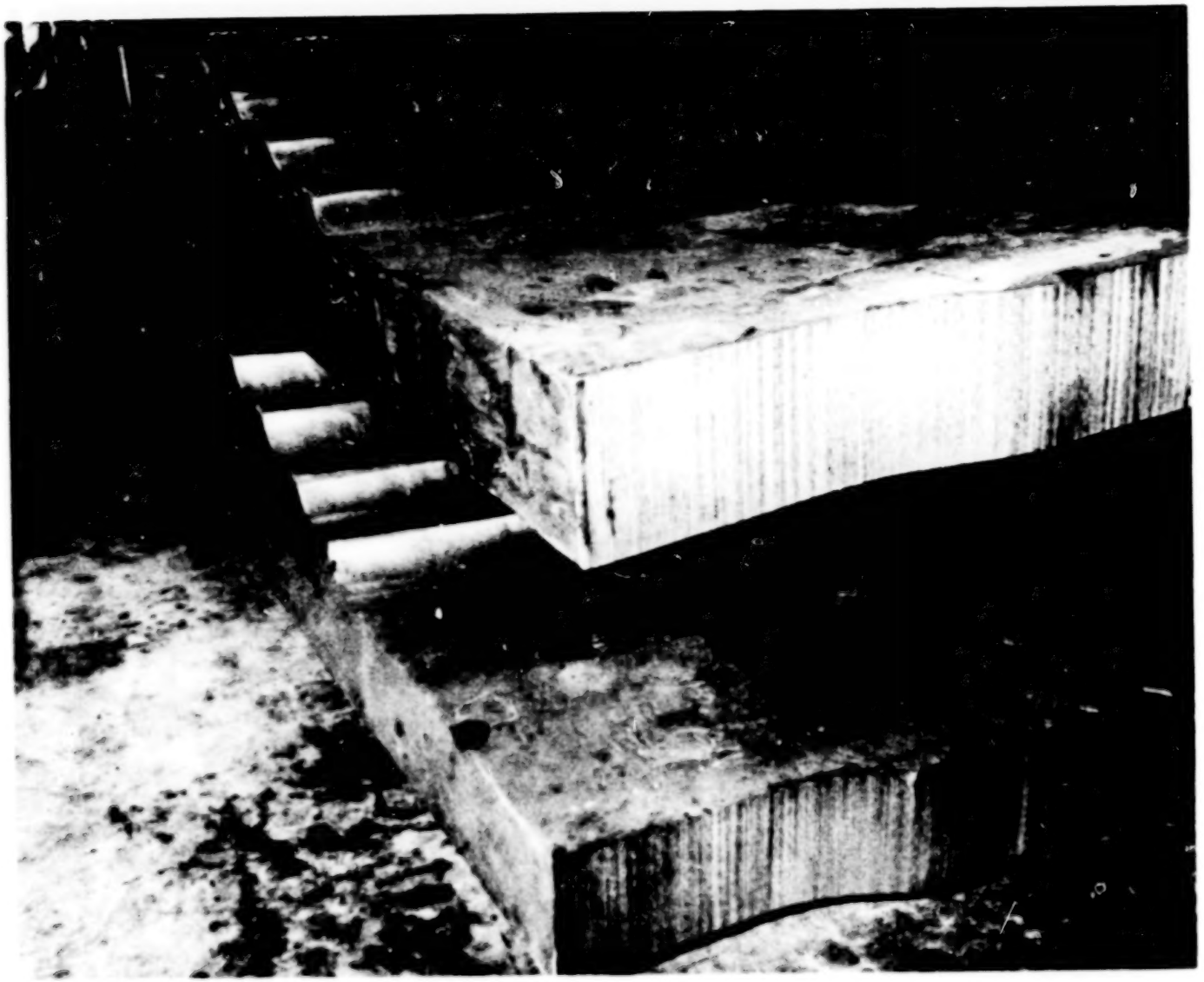


Figure 6. Contour forging P/N 14A20084 for thrust post.

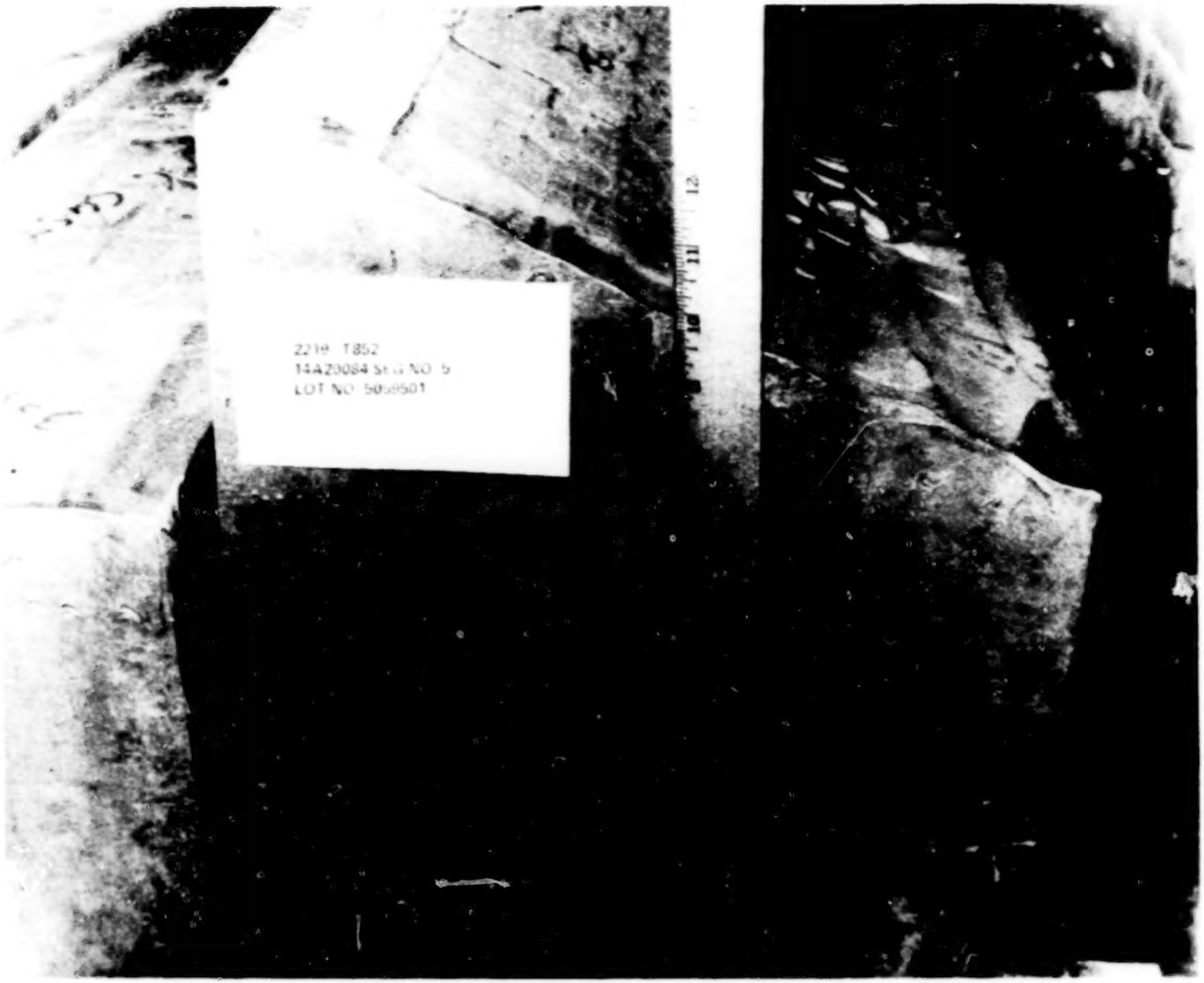


Figure 7. Thrust post — forward tapered segment 5 for destruct tests.

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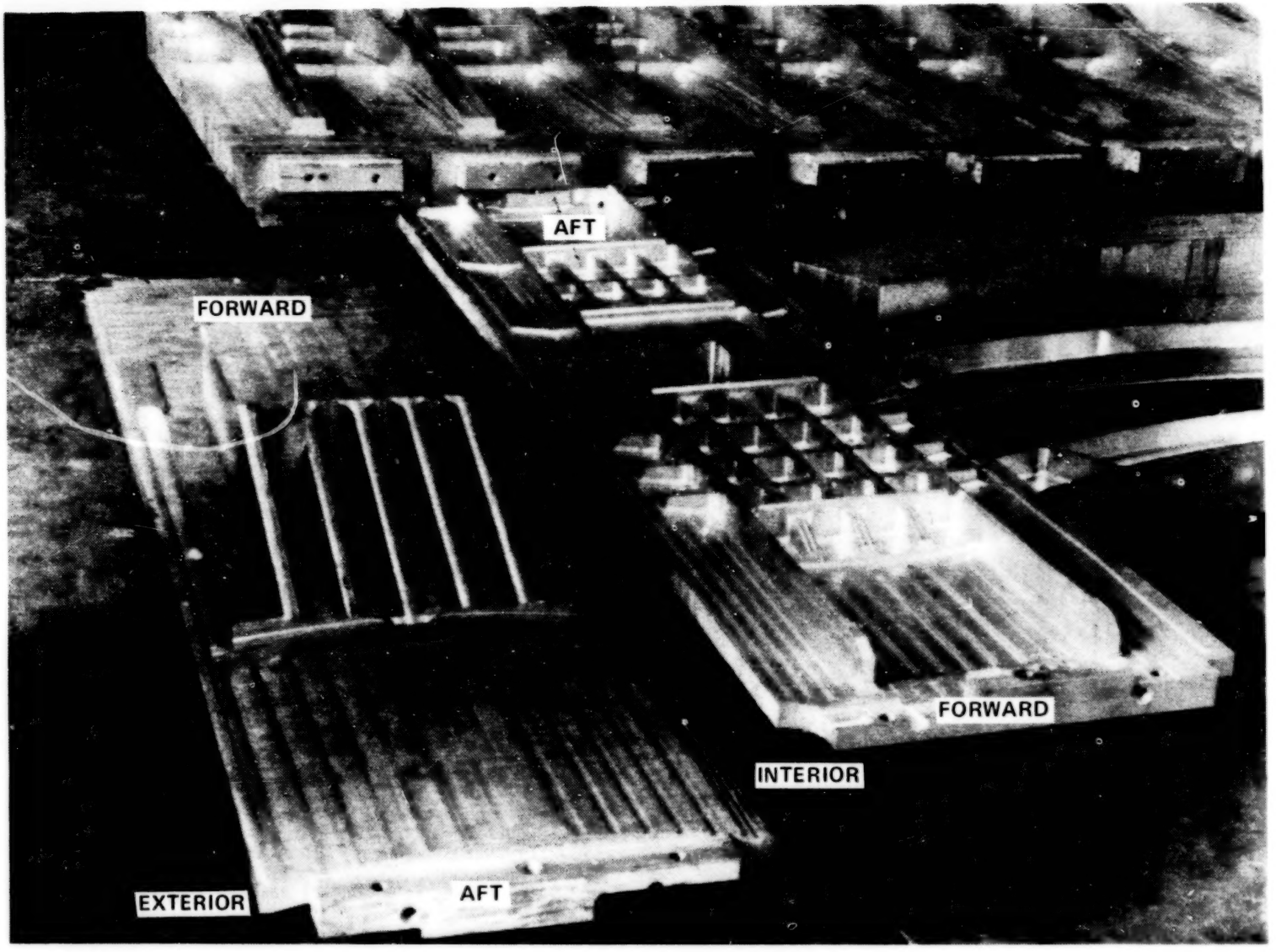


Figure 8. Thrust posts — rough machined exterior and interior.

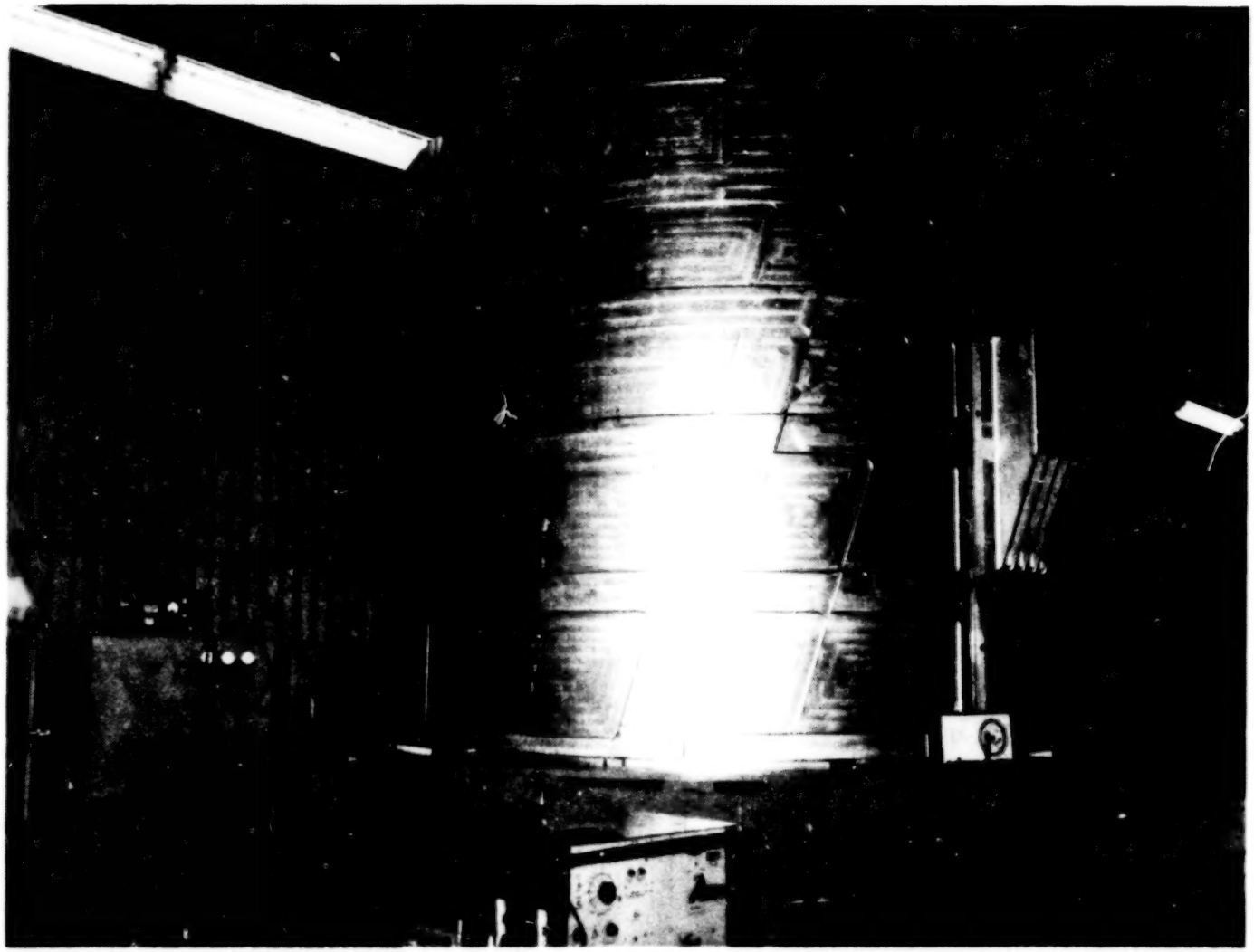
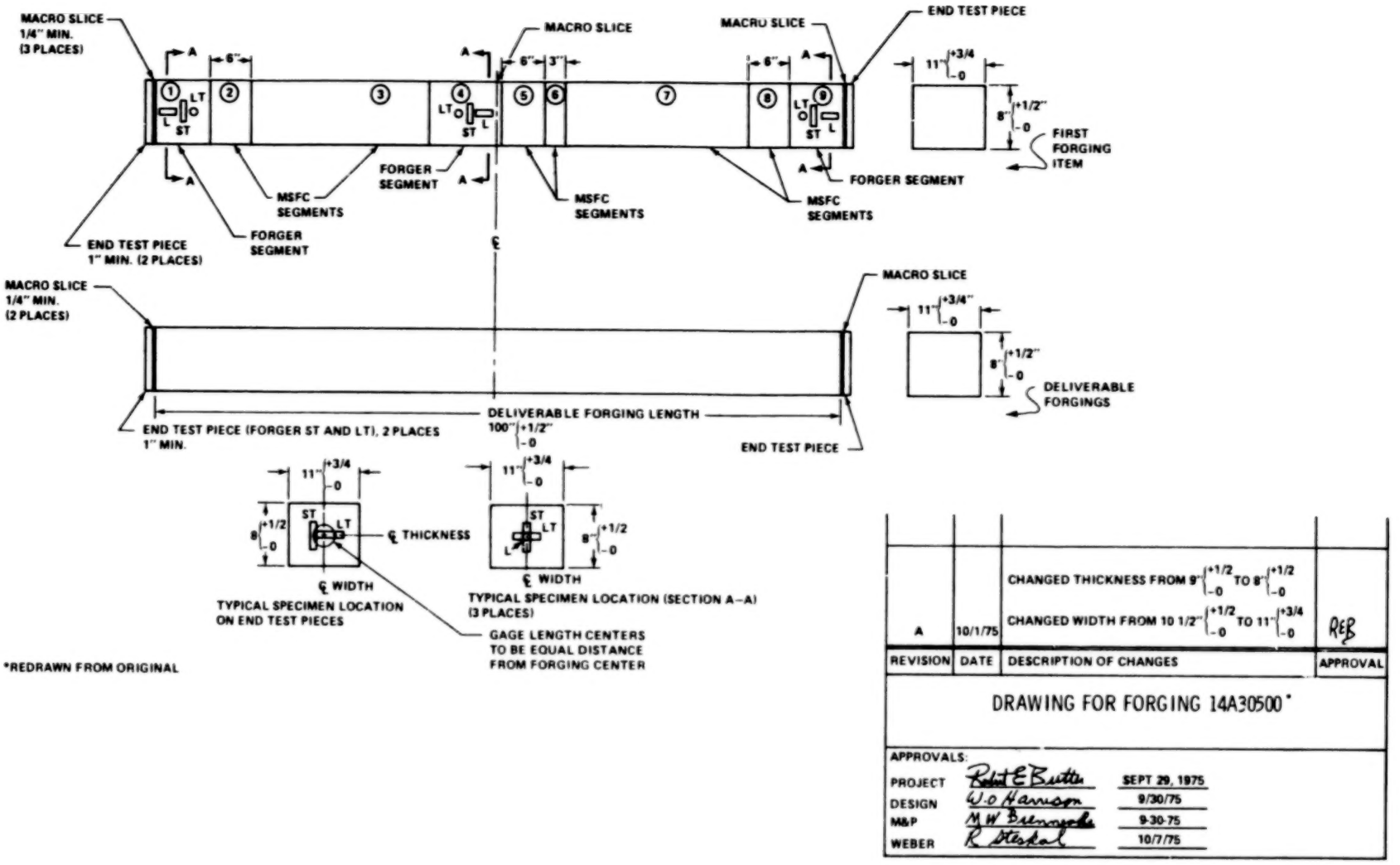


Figure 9. Forward skirt – thrust post welded to skins.


MACRO SLICE 1/4" MIN. (3 PLACES)
MACRO SLICE
MACRO SLICE
END TEST PIECE
FIRST FORGING ITEM
MSFC SEGMENTS
FORGER SEGMENT
FORGER SEGMENT
END TEST PIECE 1" MIN. (2 PLACES)
MACRO SLICE 1/4" MIN. (2 PLACES)
MACRO SLICE
DELIVERABLE FORGINGS
DELIVERABLE FORGING LENGTH 100" +1/2" -0
END TEST PIECE (FORGER ST AND LT), 2 PLACES 1" MIN.
END TEST PIECE
℄ THICKNESS
℄ WIDTH
TYPICAL SPECIMEN LOCATION ON END TEST PIECES
TYPICAL SPECIMEN LOCATION (SECTION A–A) (3 PLACES)
GAGE LENGTH CENTERS TO BE EQUAL DISTANCE FROM FORGING CENTER
*REDRAWN FROM ORIGINAL

REVISION	DATE	DESCRIPTION OF CHANGES	APPROVAL
A	10/1/75	CHANGED THICKNESS FROM 9" +1/2 -0 TO 8" +1/2 -0 CHANGED WIDTH FROM 10 1/2" +1/2 -0 TO 11" +3/4 -0	REB

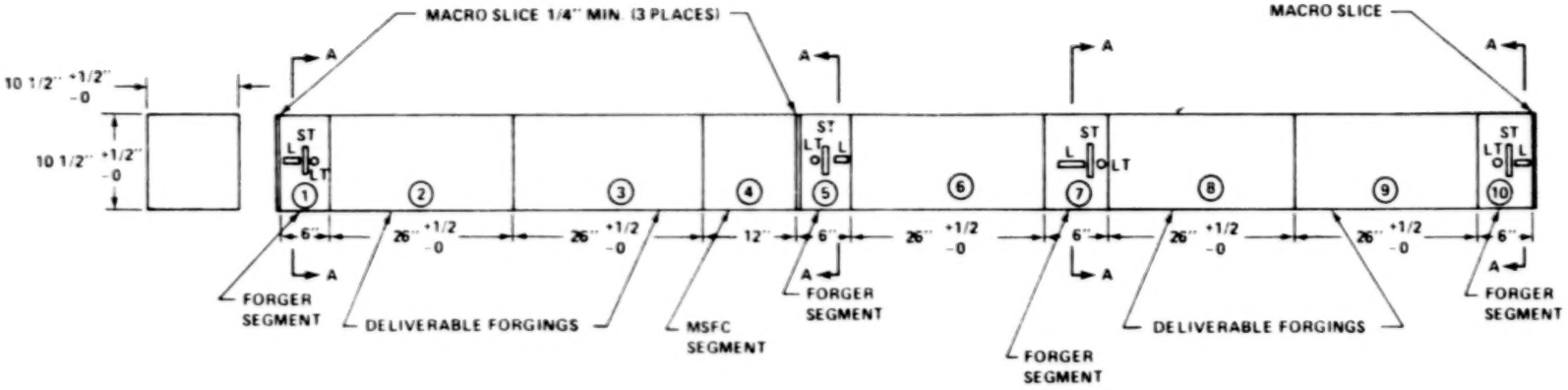
DRAWING FOR FORGING 14A30500*

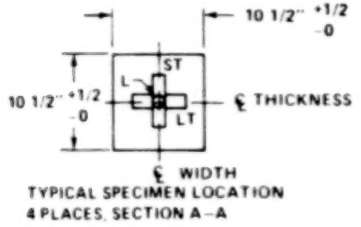
APPROVALS:

PROJECT	Robert E Butler	SEPT 29, 1975
DESIGN	W.O Harrison	9/30/75
M&P	M W Brennecke	9-30-75
WEBER	R Steskal	10/7/75

Figure 10. Dimensions and layout for rectangular hand forging 14A30500.

15





*REDRAWN FROM ORIGINAL

REVISION	DATE	DESCRIPTION OF CHANGES	APPROVAL
A	10/1/75	INCREASED WIDTH & THICKNESS FROM 10" +1/2 -0 TO 10 1/2" +1/2 -0	RCB

DRAWING FOR FORGING 14A30905*

APPROVALS		
PROJECT	Robert E Bullock	SEPT 29, '75
DESIGN	W. O. Harrison	9-30-75
M&P	W H Brenneke	9/30/75
WEBER	R Stekal	10/7/75

Figure 11. Dimensions and layout for rectangular hand forging 14A30905.

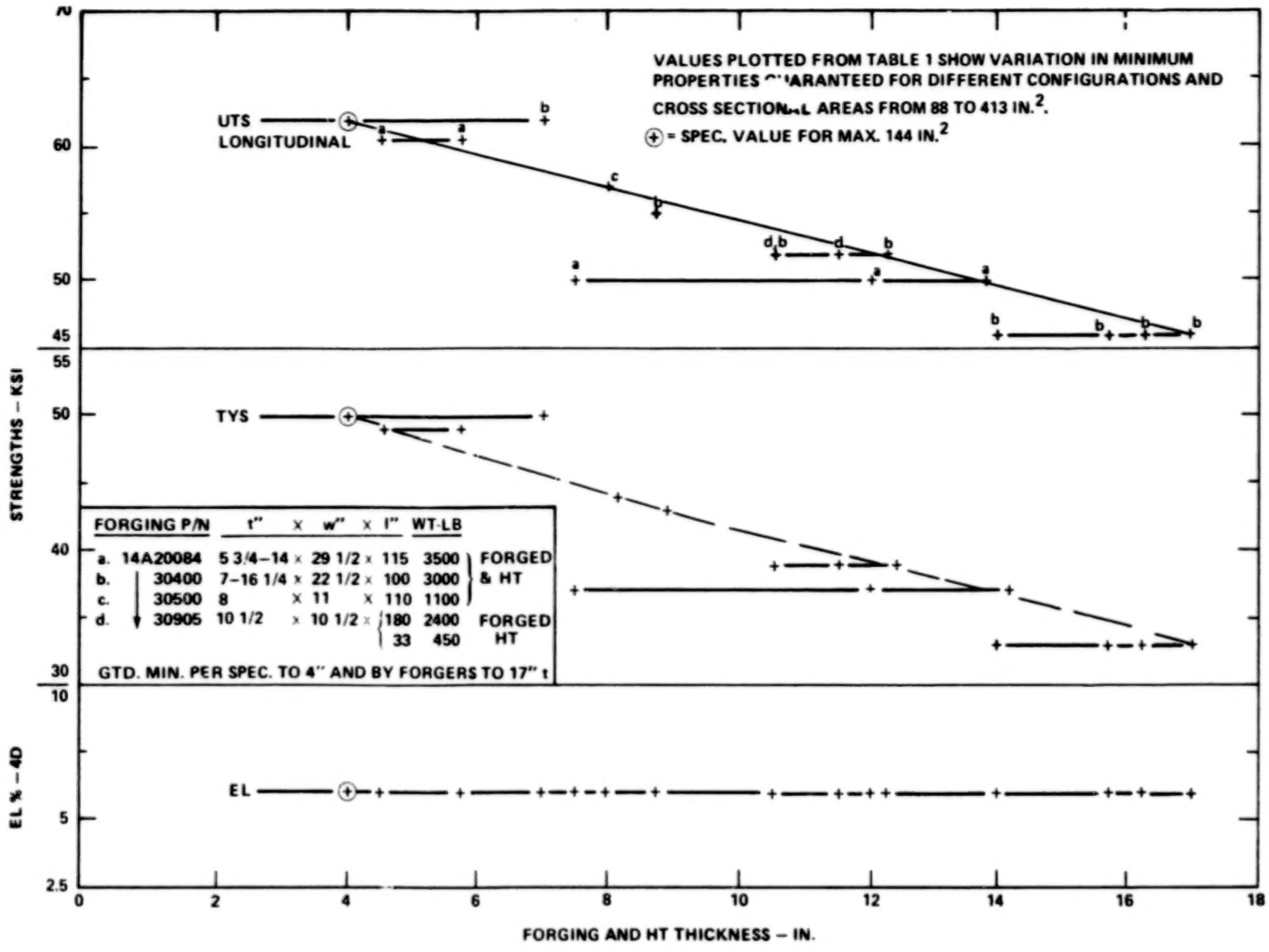

VALUES PLOTTED FROM TABLE 1 SHOW VARIATION IN MINIMUM PROPERTIES GUARANTEED FOR DIFFERENT CONFIGURATIONS AND CROSS SECTIONAL AREAS FROM 88 TO 413 IN.2.
⊕ = SPEC. VALUE FOR MAX. 144 IN.2
UTS
LONGITUDINAL
TYS
EL
STRENGTHS – KSI
EL % – 4D
FORGING AND HT THICKNESS – IN.
FORGING P/N t" x w" x l" WT-LB
a. 14A20084 5 3/4–14 x 29 1/2 x 115 3500 FORGED & HT
b. 30400 7–16 1/4 x 22 1/2 x 100 3000 FORGED & HT
c. 30500 8 x 11 x 110 1100 FORGED & HT
d. 30905 10 1/2 x 10 1/2 x 180 2400 FORGED HT
33 450 FORGED HT
GTD. MIN. PER SPEC. TO 4" AND BY FORGERS TO 17" t

Figure 12. 2219-T852 Al hand forgings — rectangular and contour — guaranteed longitudinal properties — 1974-5.

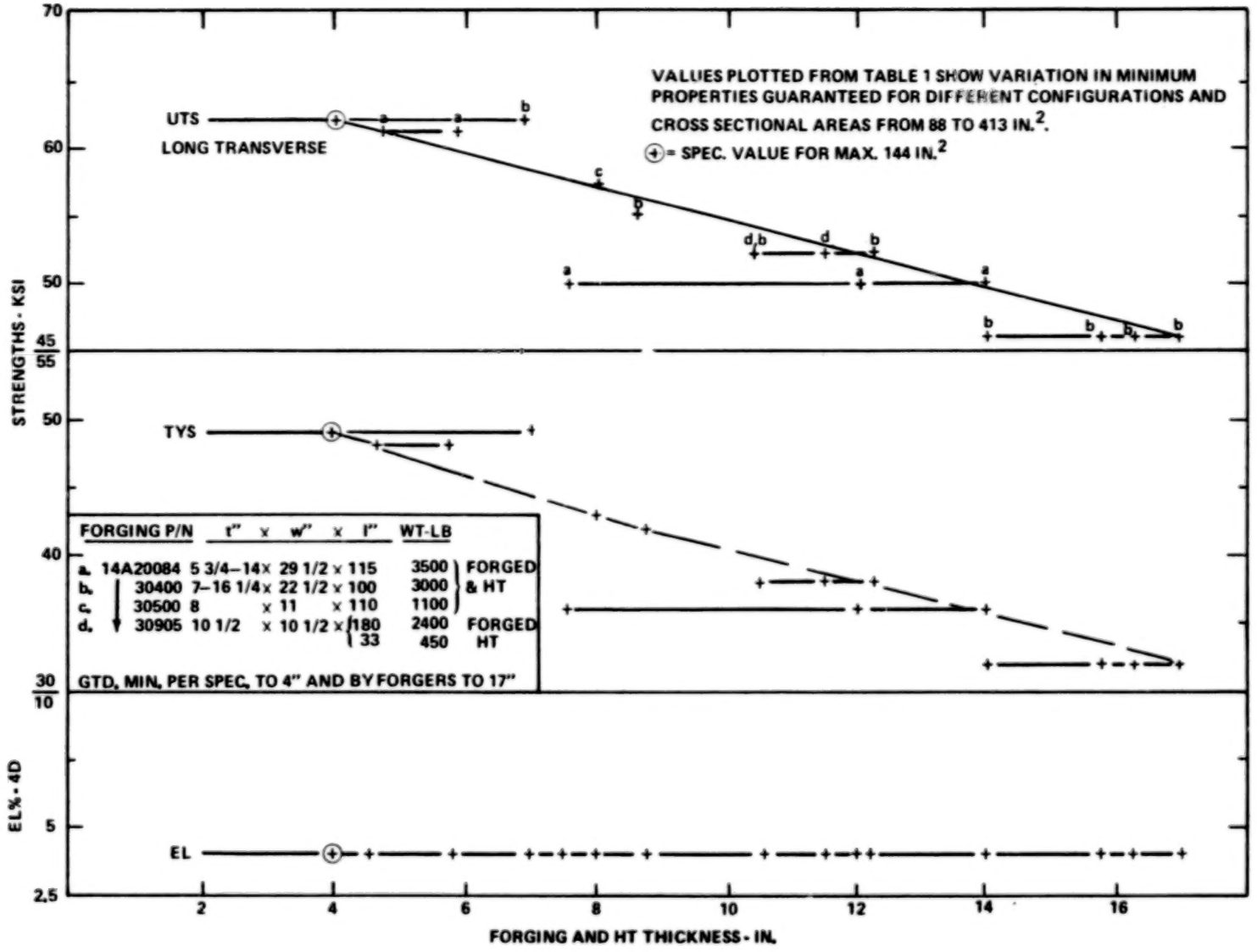

VALUES PLOTTED FROM TABLE 1 SHOW VARIATION IN MINIMUM PROPERTIES GUARANTEED FOR DIFFERENT CONFIGURATIONS AND CROSS SECTIONAL AREAS FROM 88 TO 413 IN.2.
⊕ = SPEC. VALUE FOR MAX. 144 IN.2
UTS
LONG TRANSVERSE
TYS
EL
STRENGTHS - KSI
EL% - 4D
FORGING AND HT THICKNESS - IN.
FORGING P/N t" x w" x l" WT-LB
a. 14A20084 5 3/4–14 x 29 1/2 x 115 3500 FORGED
b. 30400 7–16 1/4 x 22 1/2 x 100 3000 & HT
c. 30500 8 x 11 x 110 1100
d. 30905 10 1/2 x 10 1/2 x 180 2400 FORGED
33 450 HT
GTD. MIN. PER SPEC. TO 4" AND BY FORGERS TO 17"

Figure 13. 2219-T852 Al hand forgings — rectangular and contour — guaranteed long transverse properties — 1974-5.

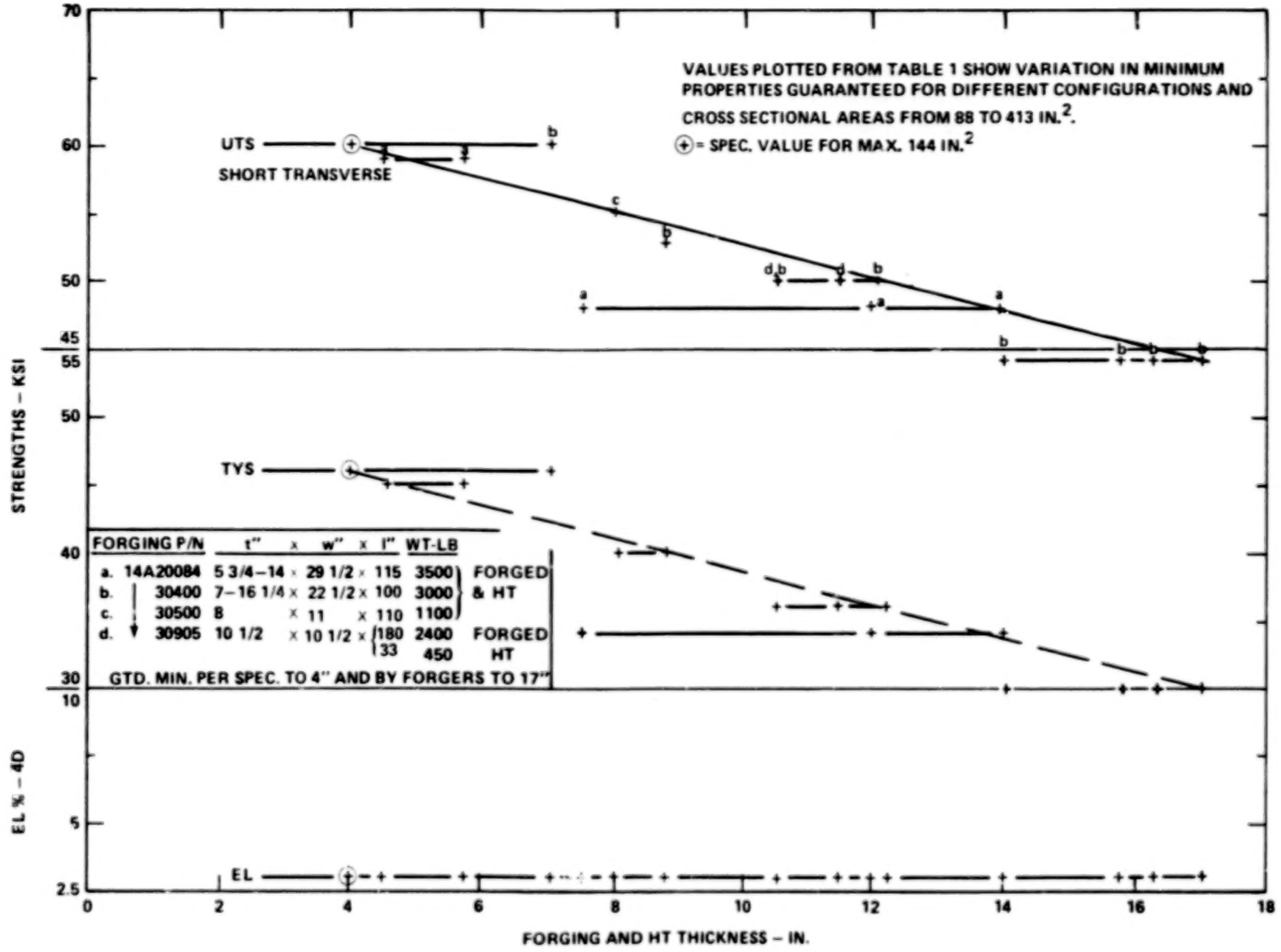


Figure 14. 2219-T852 Al hand forgings — rectangular and contour — guaranteed short transverse properties — 1974-5.

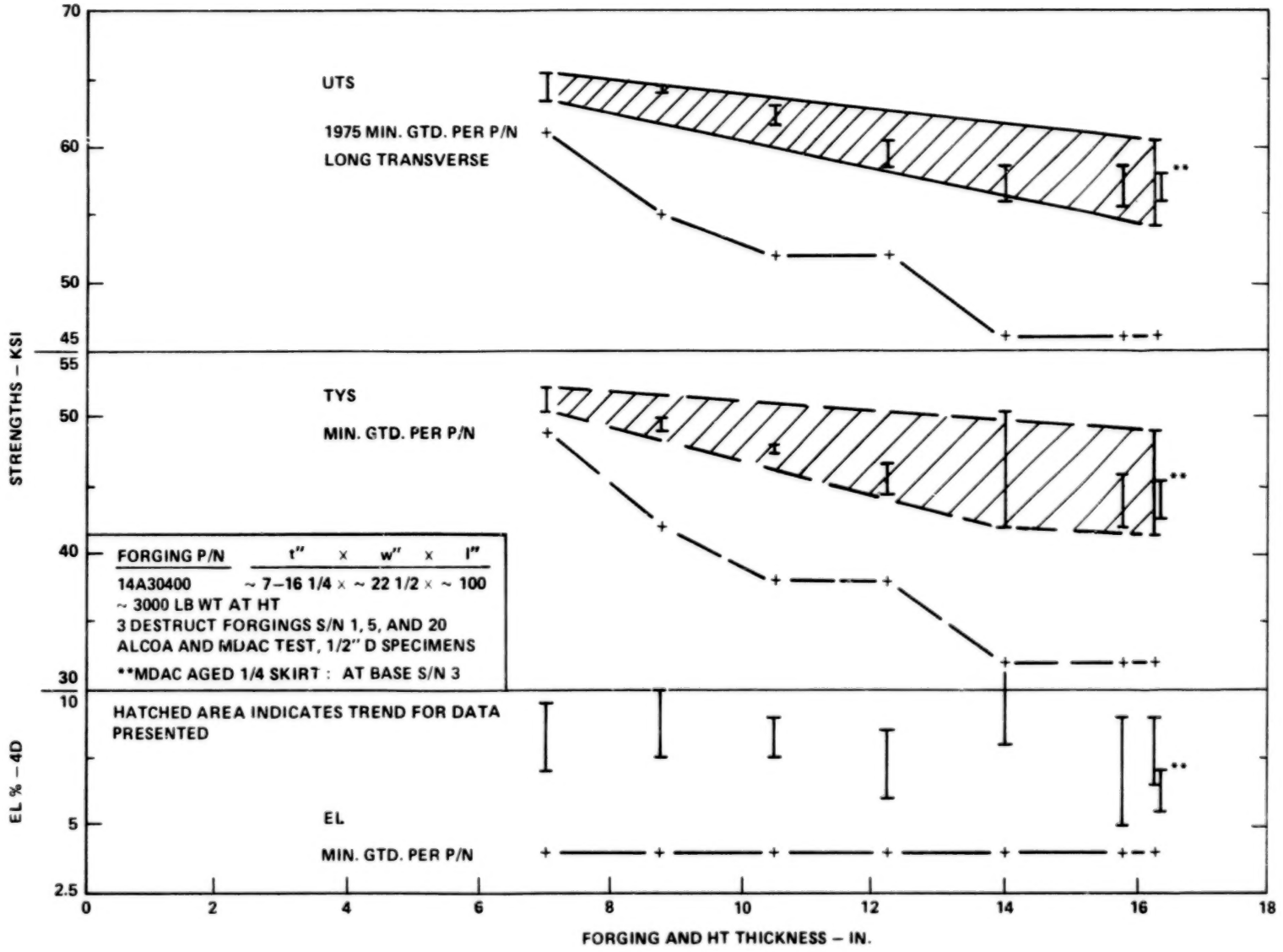

UTS
1975 MIN. GTD. PER P/N
LONG TRANSVERSE
TYS
MIN. GTD. PER P/N
EL
MIN. GTD. PER P/N
STRENGTHS – KSI
EL % – 4D
FORGING AND HT THICKNESS – IN.
FORGING P/N t" x w" x l"
14A30400 ~ 7–16 1/4 x ~ 22 1/2 x ~ 100
~ 3000 LB WT AT HT
3 DESTRUCT FORGINGS S/N 1, 5, AND 20
ALCOA AND MDAC TEST, 1/2" D SPECIMENS
**MDAC AGED 1/4 SKIRT : AT BASE S/N 3
HATCHED AREA INDICATES TREND FOR DATA PRESENTED

Figure 15. 2219-T852 Al contour hand forging 14A30400 — long transverse strength per P/N guarantee — destruct.

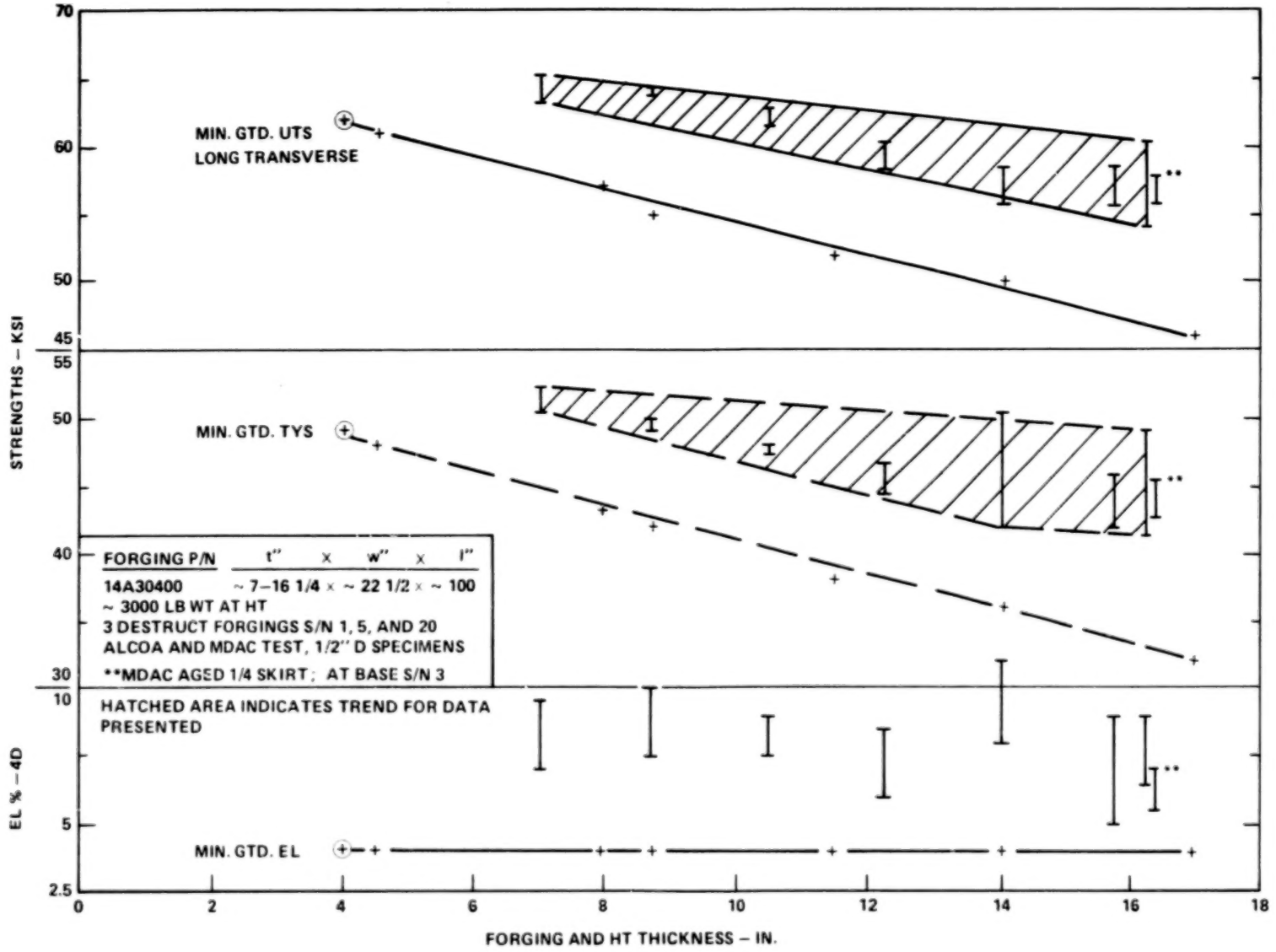

STRENGTHS – KSI
EL % – 4D
MIN. GTD. UTS
LONG TRANSVERSE
MIN. GTD. TYS
MIN. GTD. EL
FORGING P/N t" x w" x l"
14A30400 ~ 7–16 1/4 x ~ 22 1/2 x ~ 100
~ 3000 LB WT AT HT
3 DESTRUCT FORGINGS S/N 1, 5, AND 20
ALCOA AND MDAC TEST, 1/2" D SPECIMENS
**MDAC AGED 1/4 SKIRT; AT BASE S/N 3
HATCHED AREA INDICATES TREND FOR DATA PRESENTED
FORGING AND HT THICKNESS – IN.

Figure 16. 2219-T852 Al contour hand forging 14A30400 — long transverse strength-versus-thickness — destruct.

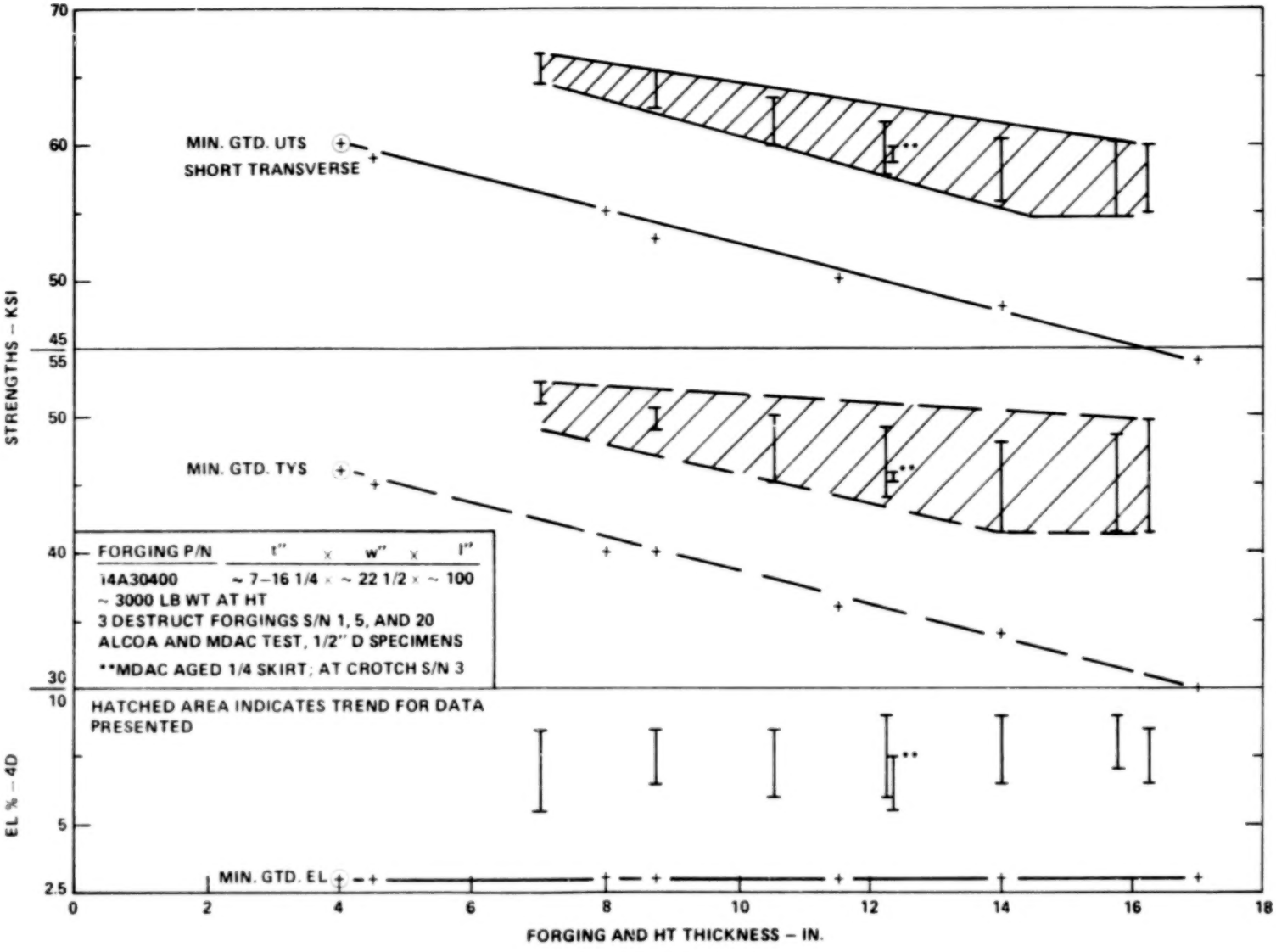


Figure 17. 2219-T852 Al contour hand forging 14A30400 — short transverse strength-versus-thickness — destruct.

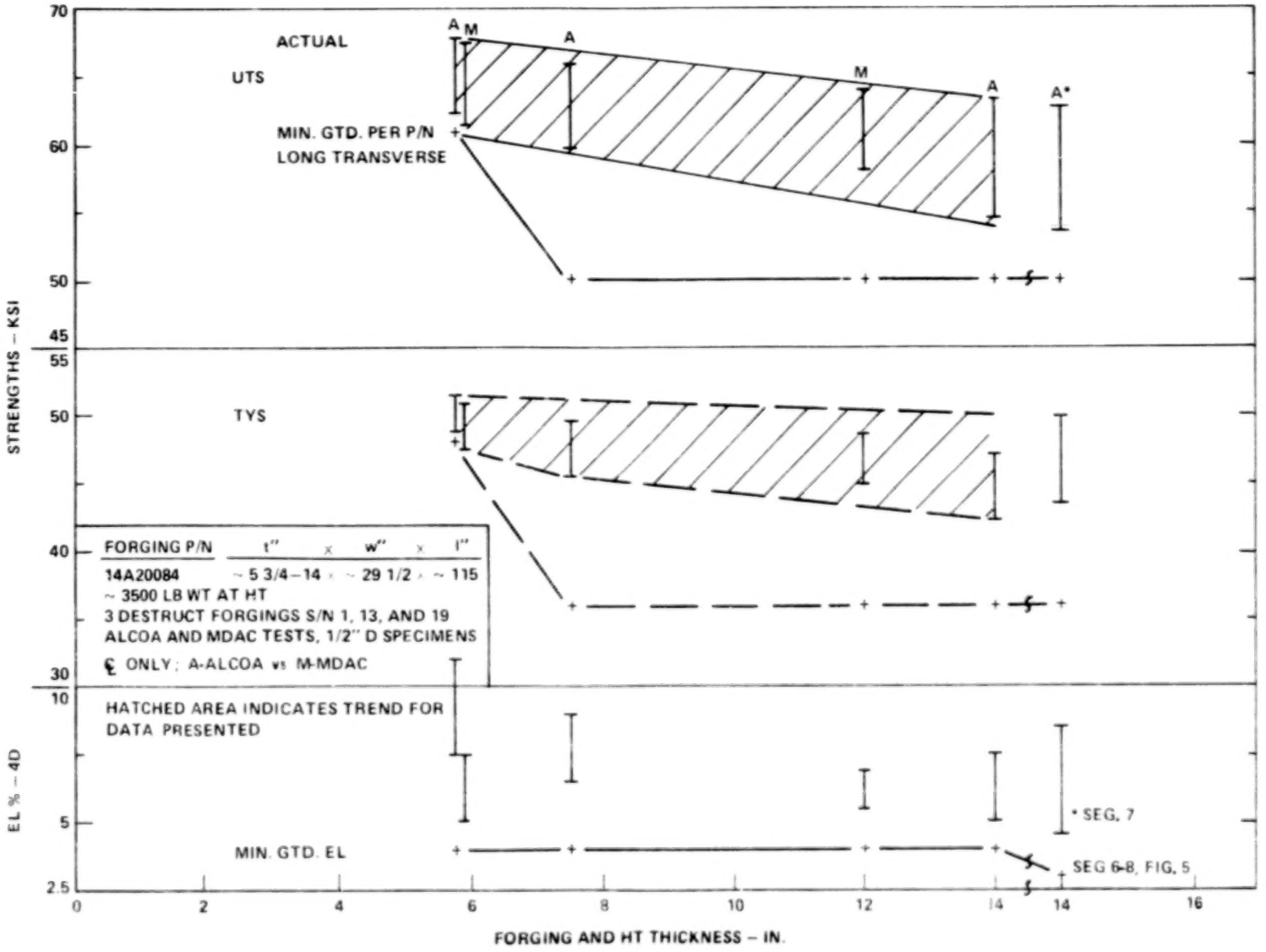

ACTUAL
UTS
MIN. GTD. PER P/N
LONG TRANSVERSE
TYS
FORGING P/N
t" x w" x l"
14A20084 ~ 5 3/4–14 x ~ 29 1/2 x ~ 115
~ 3500 LB WT AT HT
3 DESTRUCT FORGINGS S/N 1, 13, AND 19
ALCOA AND MDAC TESTS, 1/2" D SPECIMENS
℄ ONLY; A-ALCOA vs M-MDAC
HATCHED AREA INDICATES TREND FOR DATA PRESENTED
MIN. GTD. EL
* SEG. 7
SEG 6-8, FIG. 5
STRENGTHS – KSI
EL % – 4D
FORGING AND HT THICKNESS – IN.

Figure 18. 2219-T852 Al contour hand forging 14A20084 — long transverse strength per P/N guarantee — destruct — ℄ only.

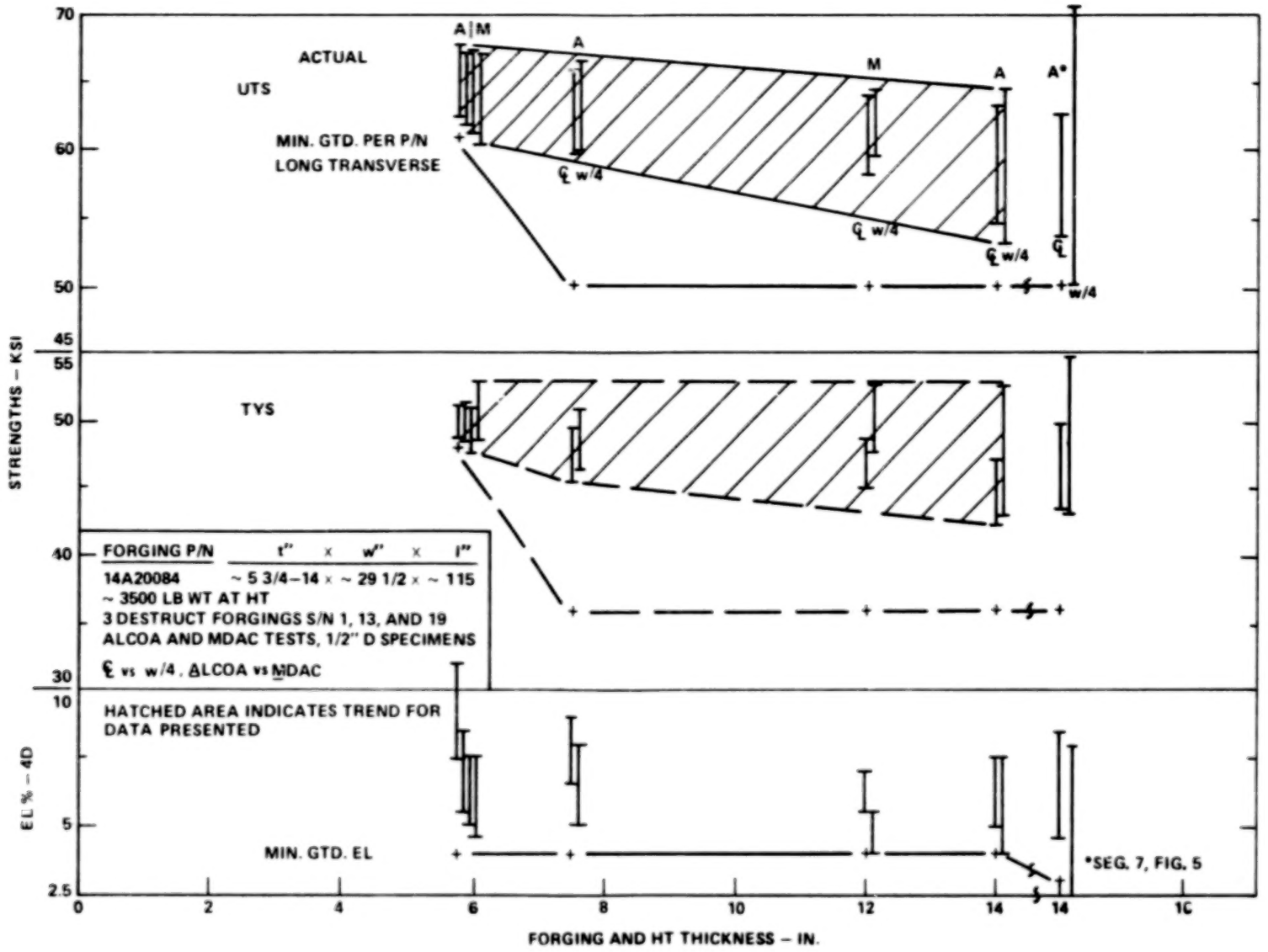

ACTUAL
UTS
MIN. GTD. PER P/N
LONG TRANSVERSE
TYS
STRENGTHS – KSI
EL % – 4D
FORGING P/N
t" x w" x l"
14A20084 ~ 5 3/4–14 x ~ 29 1/2 x ~ 115
~ 3500 LB WT AT HT
3 DESTRUCT FORGINGS S/N 1, 13, AND 19
ALCOA AND MDAC TESTS, 1/2" D SPECIMENS
℄ vs w/4 , ΔALCOA vs ΔMDAC
HATCHED AREA INDICATES TREND FOR DATA PRESENTED
MIN. GTD. EL
*SEG. 7, FIG. 5
FORGING AND HT THICKNESS – IN.

Figure 19. 2219-T852 Al contour hand forging 14A20084 — long transverse strength per P/N guarantee — destruct — ℄ vs w/4.

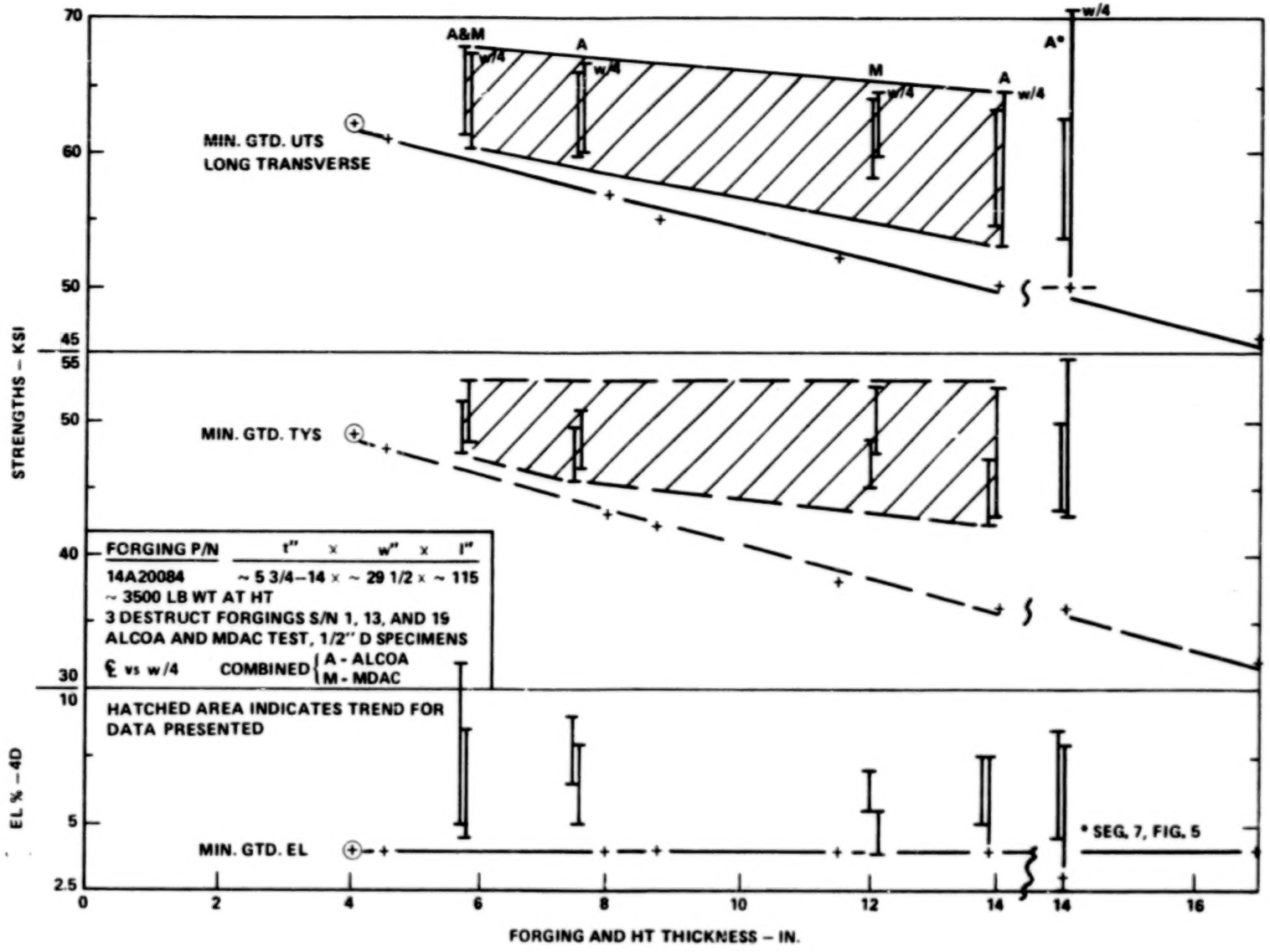

STRENGTHS – KSI
EL % – 4D
MIN. GTD. UTS
LONG TRANSVERSE
MIN. GTD. TYS
MIN. GTD. EL
A&M
A
M
A
A*
w/4
FORGING P/N
t" x w" x l"
14A20084 ~ 5 3/4–14 x ~ 29 1/2 x ~ 115
~ 3500 LB WT AT HT
3 DESTRUCT FORGINGS S/N 1, 13, AND 19
ALCOA AND MDAC TEST, 1/2" D SPECIMENS
℄ vs w/4 COMBINED { A - ALCOA M - MDAC
HATCHED AREA INDICATES TREND FOR DATA PRESENTED
* SEG. 7, FIG. 5
FORGING AND HT THICKNESS – IN.

Figure 20. 2219-T852 Al contour hand forging 14A20084 — long transverse strength-versus-thickness — destruct — ℄ -versus-w/4.

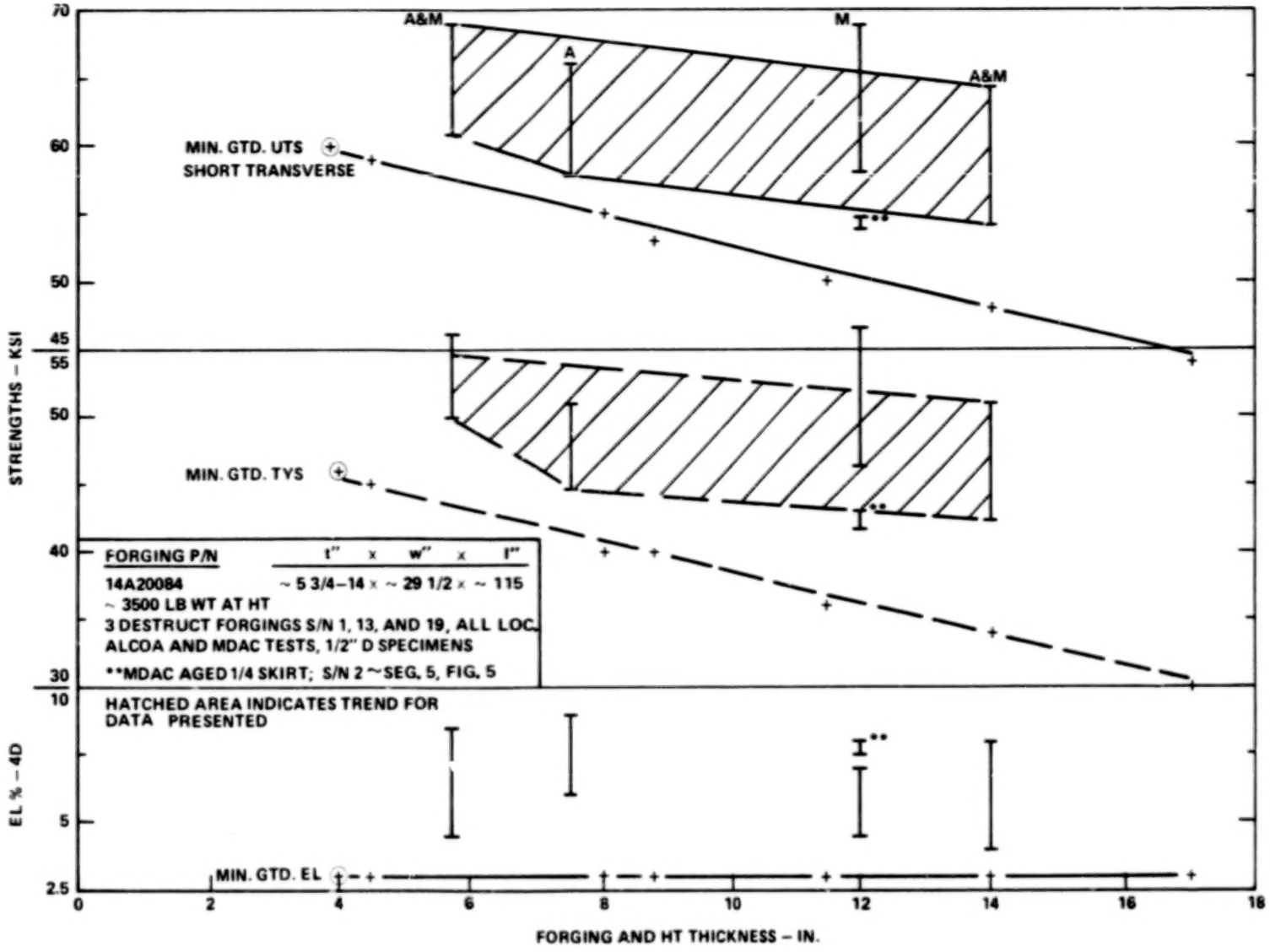


Figure 21. 2219-T852 Al contour hand forging 14A20084 — short transverse strength-versus-thickness — destruct.

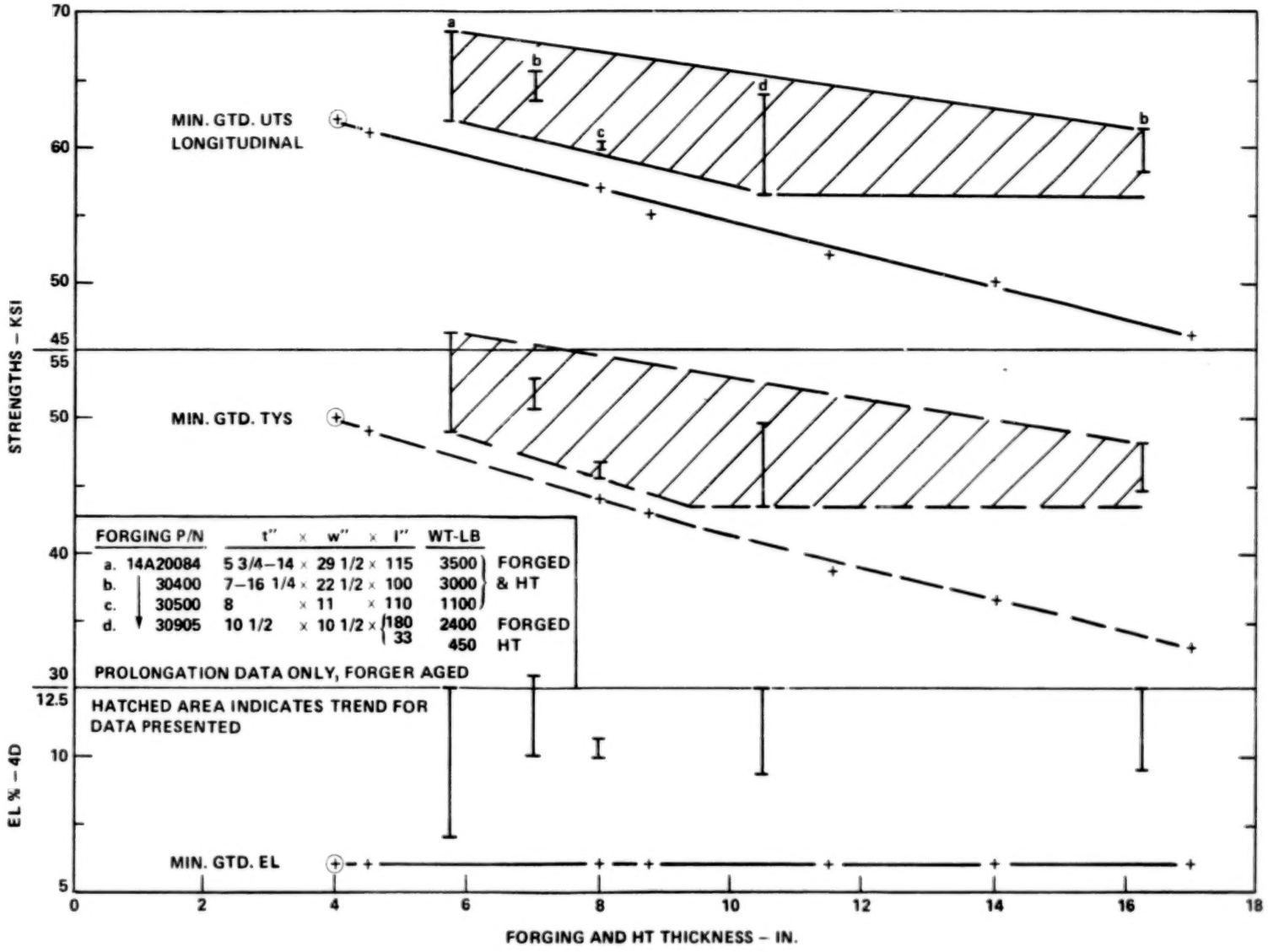

STRENGTHS – KSI
EL % – 4D
MIN. GTD. UTS
LONGITUDINAL
MIN. GTD. TYS
MIN. GTD. EL
FORGING P/N
t" x w" x l"
WT-LB
a. 14A20084 5 3/4–14 x 29 1/2 x 115 3500 FORGED
b. 30400 7–16 1/4 x 22 1/2 x 100 3000 & HT
c. 30500 8 x 11 x 110 1100
d. 30905 10 1/2 x 10 1/2 x 180 2400 FORGED
33 450 HT
PROLONGATION DATA ONLY, FORGER AGED
HATCHED AREA INDICATES TREND FOR DATA PRESENTED
FORGING AND HT THICKNESS – IN.

Figure 22. Combined data — 2219-T852 Al hand forgings — longitudinal strength-versus-thickness — prolongations.

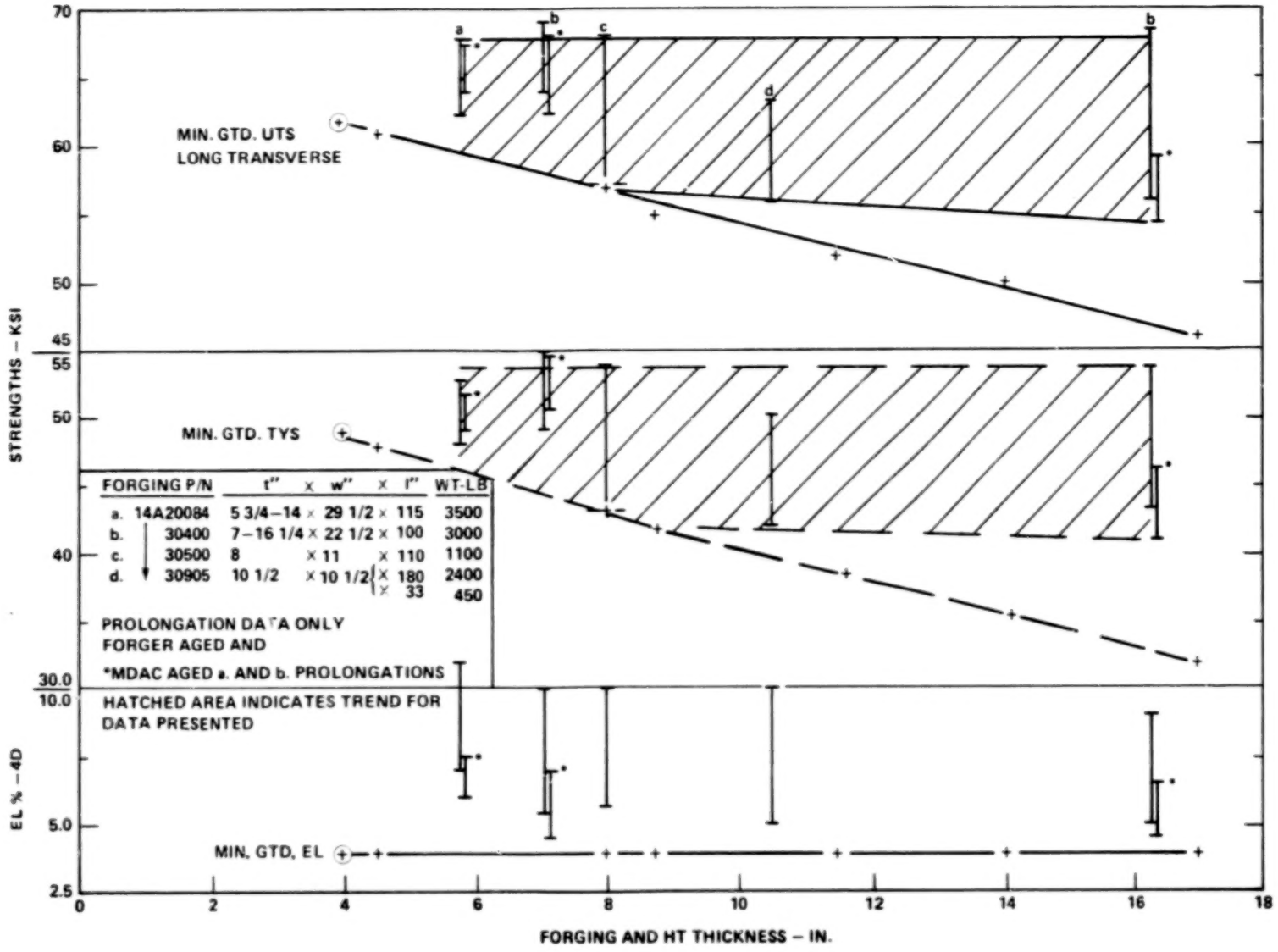

MIN. GTD. UTS
LONG TRANSVERSE
MIN. GTD. TYS
MIN. GTD. EL
STRENGTHS – KSI
EL % – 4D
FORGING AND HT THICKNESS – IN.
FORGING P/N | t" x w" x l" | WT-LB
a. 14A20084 | 5 3/4–14 x 29 1/2 x 115 | 3500
b. 30400 | 7–16 1/4 x 22 1/2 x 100 | 3000
c. 30500 | 8 x 11 x 110 | 1100
d. 30905 | 10 1/2 x 10 1/2 x 180 | 2400
x 33 | 450
PROLONGATION DATA ONLY
FORGER AGED AND
*MDAC AGED a. AND b. PROLONGATIONS
HATCHED AREA INDICATES TREND FOR DATA PRESENTED

Figure 23. Combined data — 2219-T852 Al hand forgings — long transverse strength-versus-thickness — prolongations.

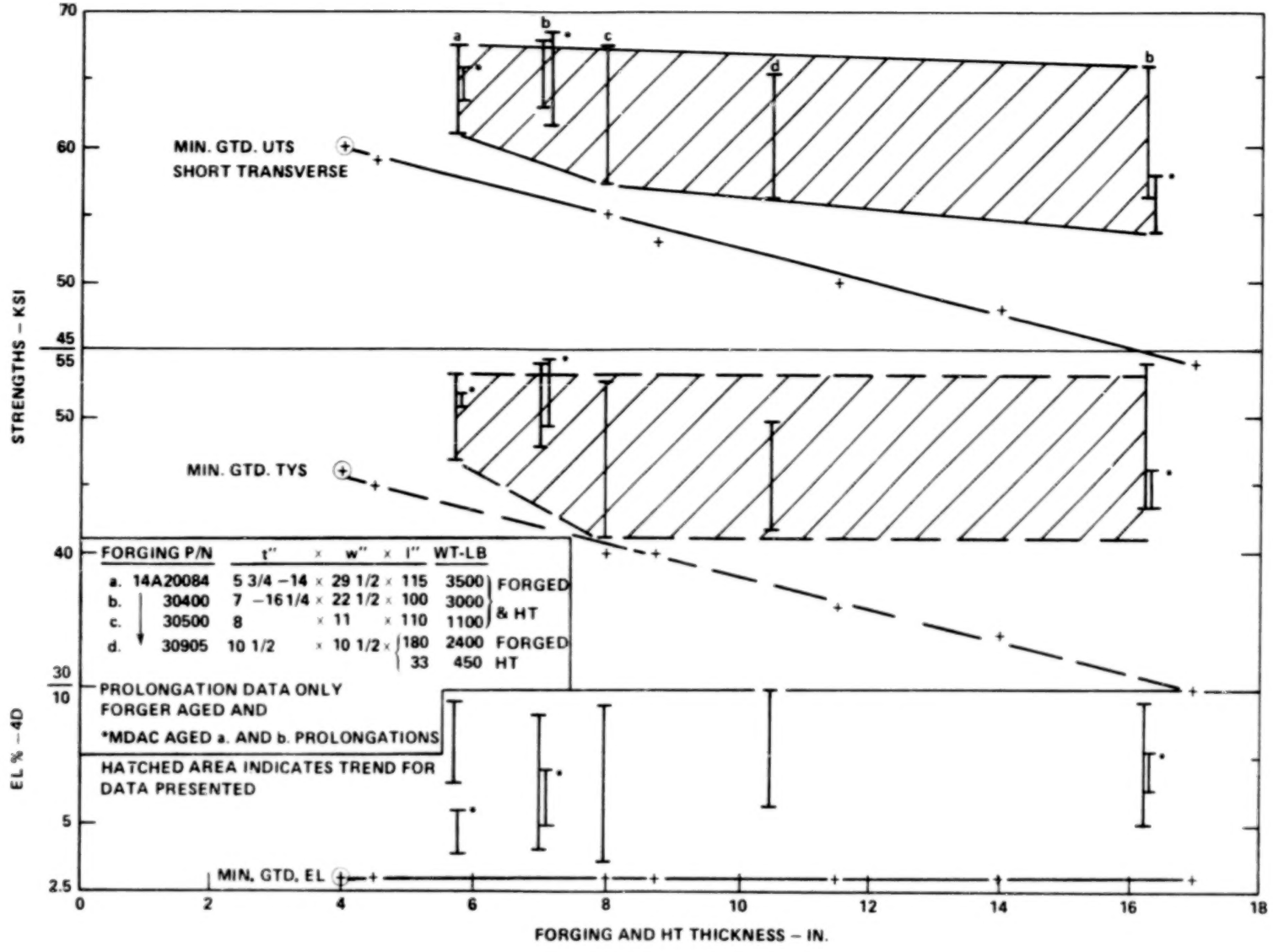

STRENGTHS – KSI
EL % – 4D
FORGING AND HT THICKNESS – IN.
MIN. GTD. UTS
SHORT TRANSVERSE
MIN. GTD. TYS
MIN. GTD. EL
FORGING P/N t" x w" x l" WT-LB
a. 14A20084 5 3/4 –14 x 29 1/2 x 115 3500 FORGED
b. 30400 7 –16 1/4 x 22 1/2 x 100 3000 & HT
c. 30500 8 x 11 x 110 1100
d. 30905 10 1/2 x 10 1/2 x 180 2400 FORGED
33 450 HT
PROLONGATION DATA ONLY
FORGER AGED AND
*MDAC AGED a. AND b. PROLONGATIONS
HATCHED AREA INDICATES TREND FOR DATA PRESENTED

Figure 24. Combined data — 2219-T852 Al hand forgings — short transverse strength-versus-thickness — prolongations.

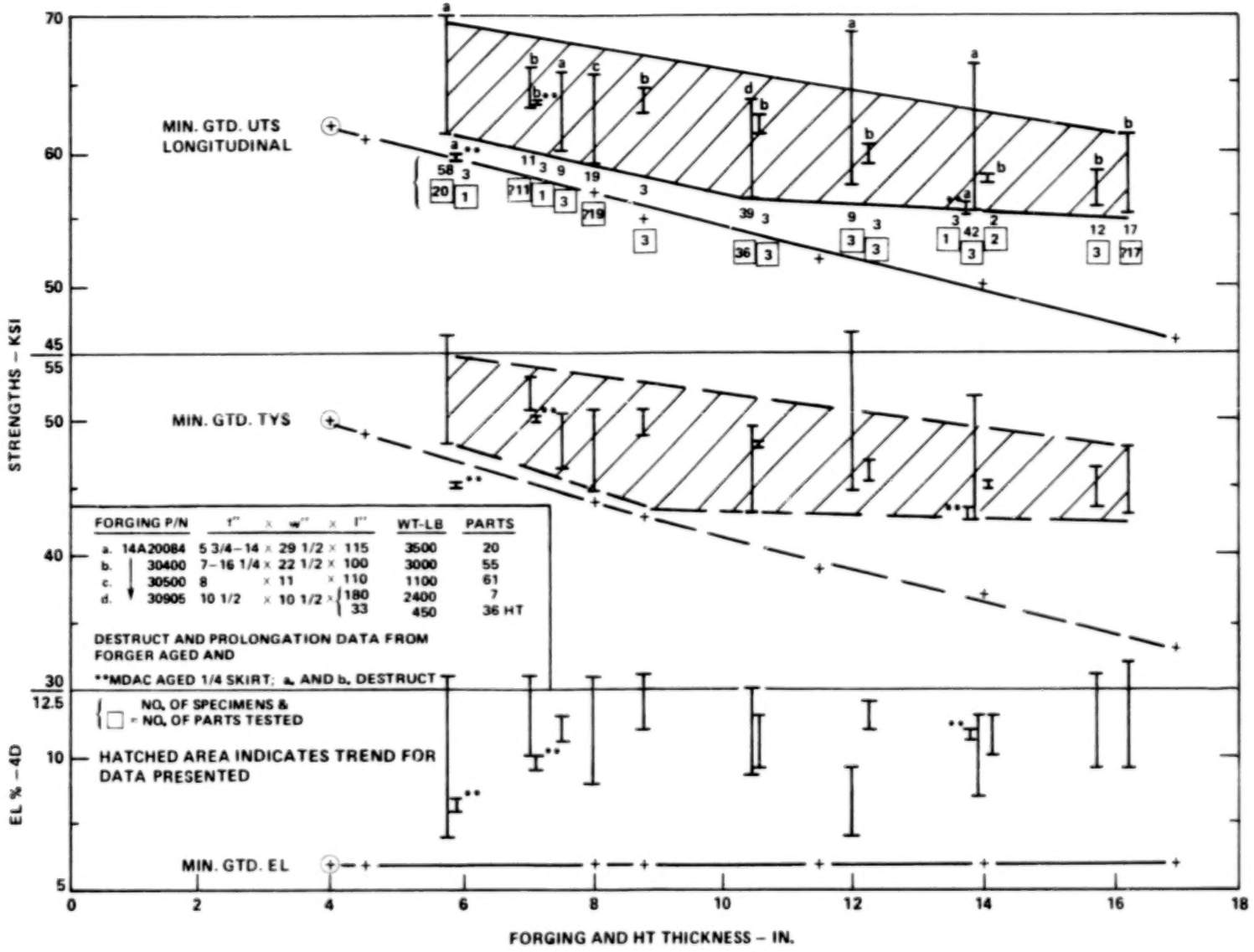


Figure 25. Combined data — 2219-T852 Al hand forgings — longitudinal strength-versus-thickness — 4 configurations.

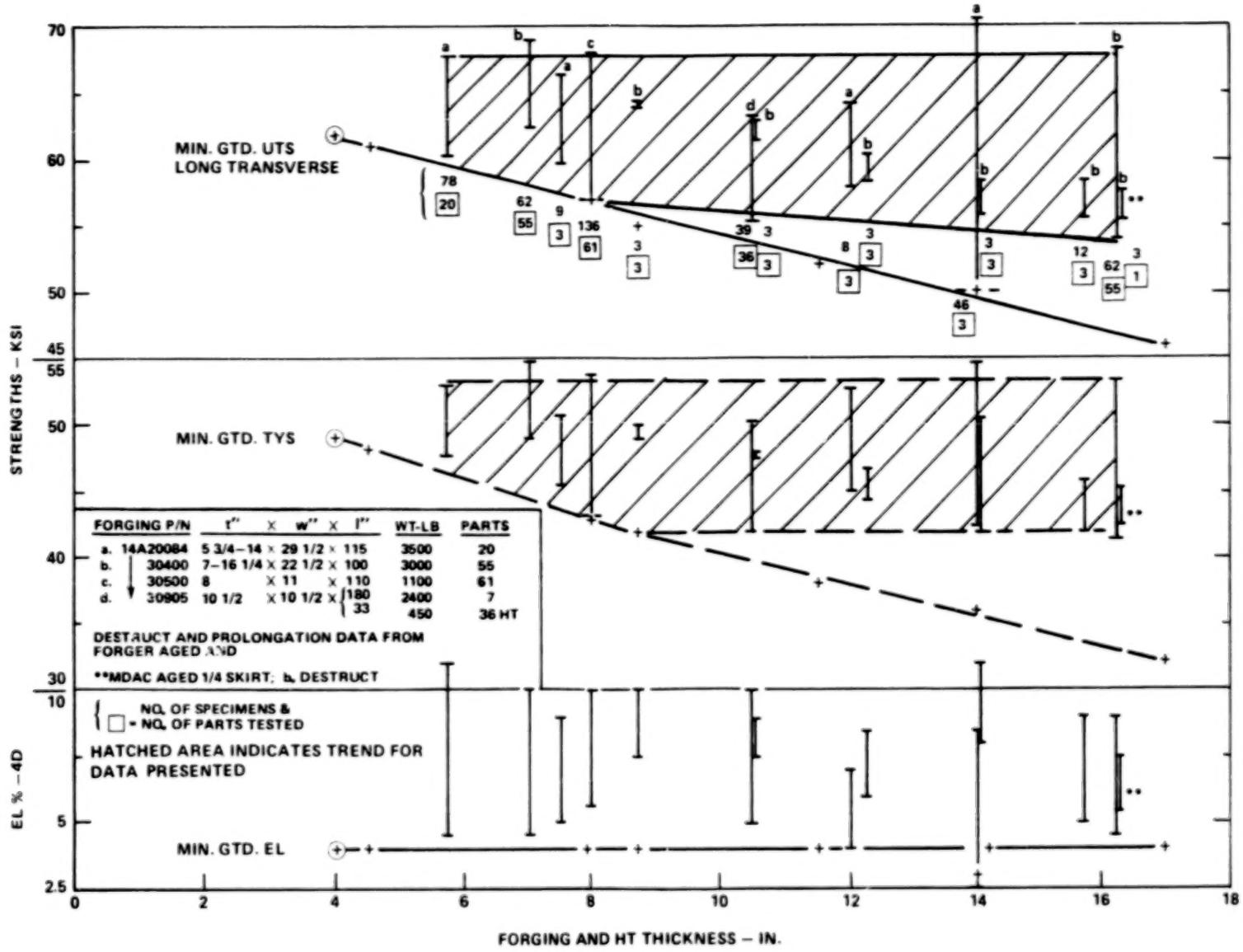

MIN. GTD. UTS
LONG TRANSVERSE
MIN. GTD. TYS
MIN. GTD. EL
STRENGTHS – KSI
EL % – 4D
FORGING AND HT THICKNESS – IN.
FORGING P/N t" X w" X l" WT-LB PARTS
a. 14A20084 5 3/4–14 X 29 1/2 X 115 3500 20
b. 30400 7–16 1/4 X 22 1/2 X 100 3000 55
c. 30500 8 X 11 X 110 1100 61
d. 30905 10 1/2 X 10 1/2 X 180 2400 7
33 450 36 HT
DESTRUCT AND PROLONGATION DATA FROM FORGER AGED AND
**MDAC AGED 1/4 SKIRT; b, DESTRUCT
NO. OF SPECIMENS & □ = NO. OF PARTS TESTED
HATCHED AREA INDICATES TREND FOR DATA PRESENTED

Figure 26. Combined data — 2219-T852 Al hand forgings — long transverse strength-versus-thickness — 4 configurations.

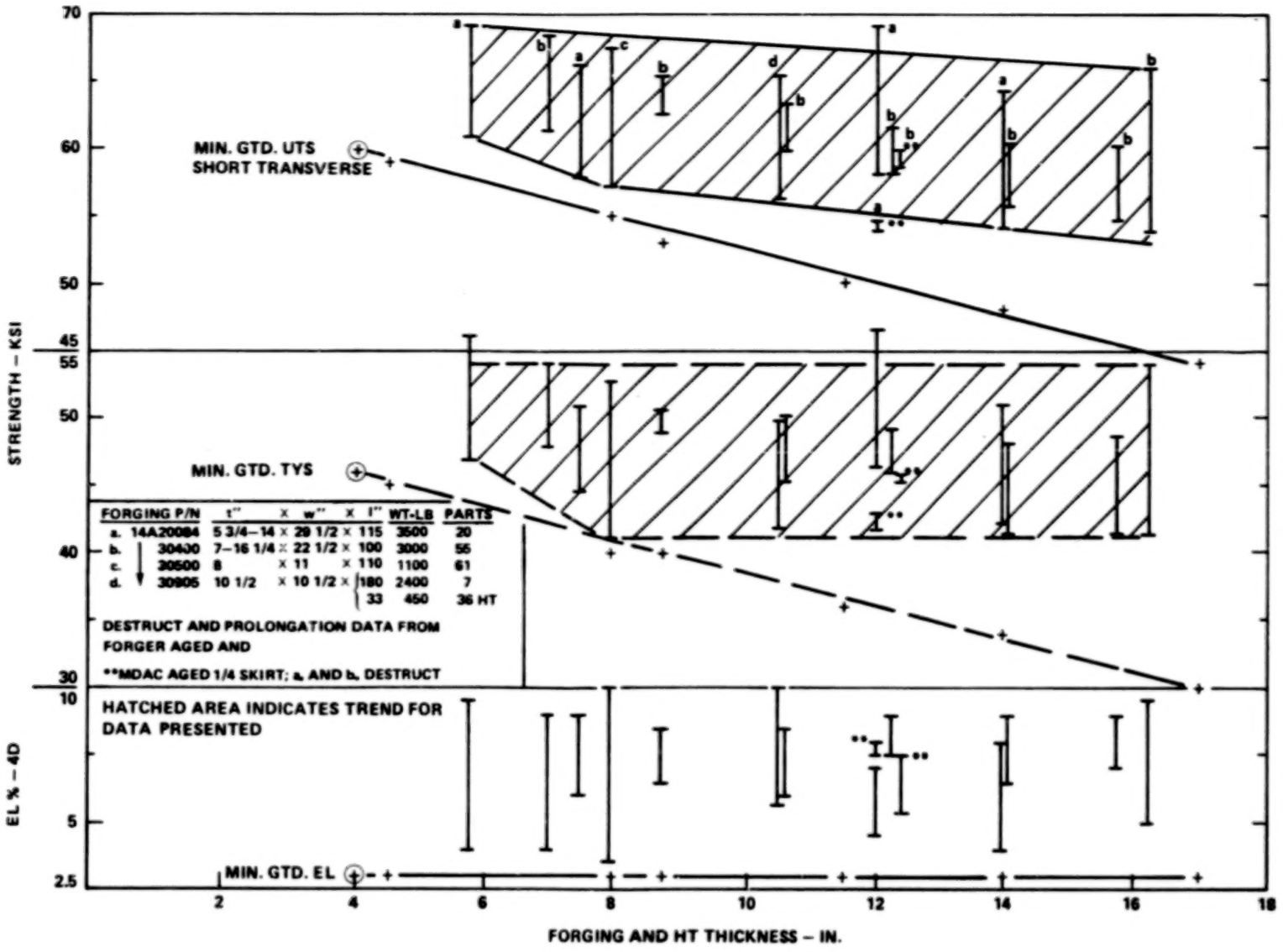

STRENGTH – KSI
EL % – 4D
MIN. GTD. UTS
SHORT TRANSVERSE
MIN. GTD. TYS
MIN. GTD. EL
FORGING P/N t" x w" x l" WT-LB PARTS
a. 14A20084 5 3/4–14 x 29 1/2 x 115 3500 20
b. 30400 7–16 1/4 x 22 1/2 x 100 3000 55
c. 30500 8 x 11 x 110 1100 61
d. 30905 10 1/2 x 10 1/2 x 180 2400 7
33 450 36 HT
DESTRUCT AND PROLONGATION DATA FROM FORGER AGED AND
**MDAC AGED 1/4 SKIRT; a. AND b. DESTRUCT
HATCHED AREA INDICATES TREND FOR DATA PRESENTED
FORGING AND HT THICKNESS – IN.

Figure 27. Combined data — 2219-T852 Al hand forgings — short transverse strength-versus-thickness — 4 configurations.

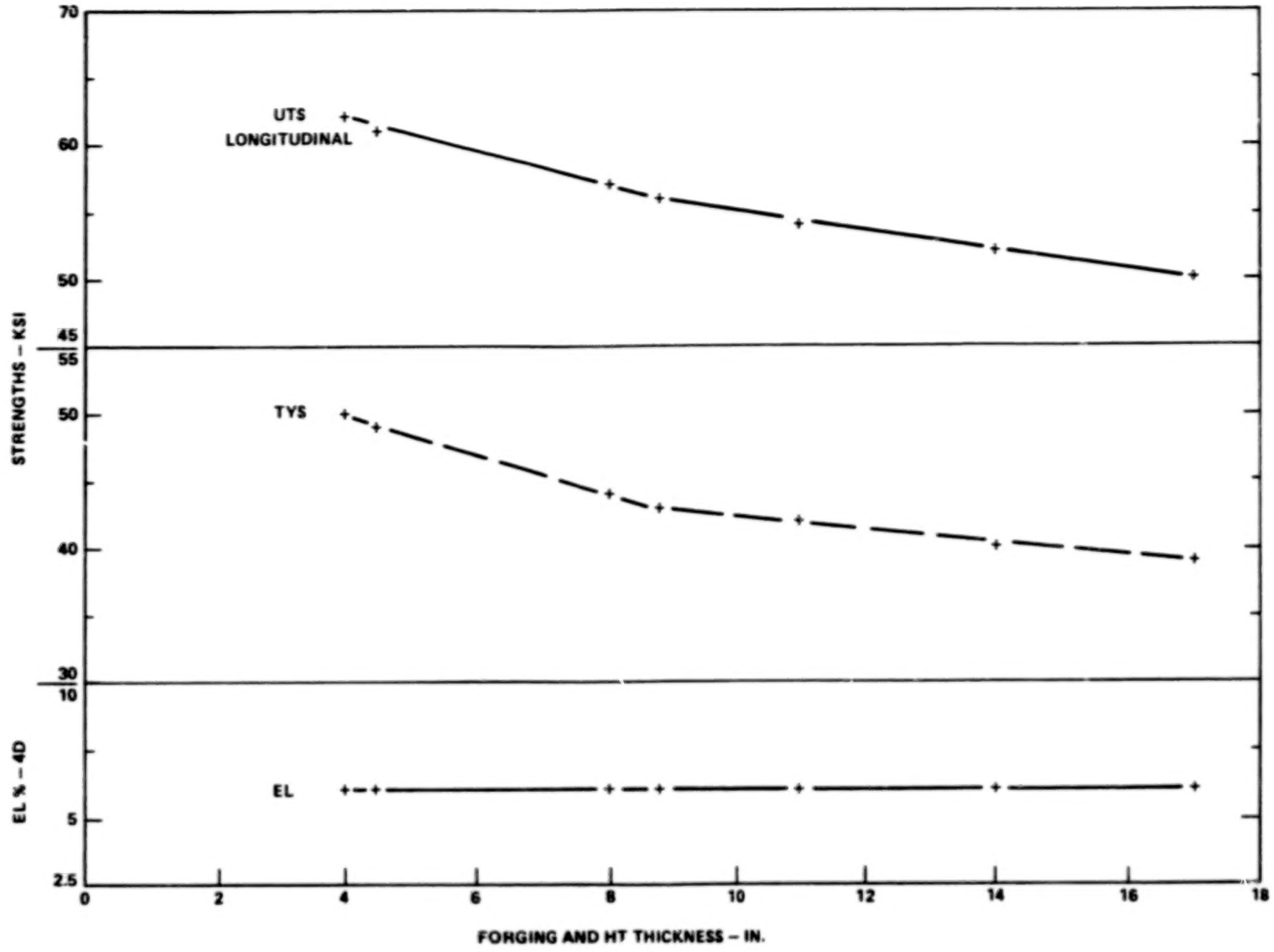


Figure 28. 2219-T852 Al hand forgings — rectangular and contour — proposed longitudinal properties

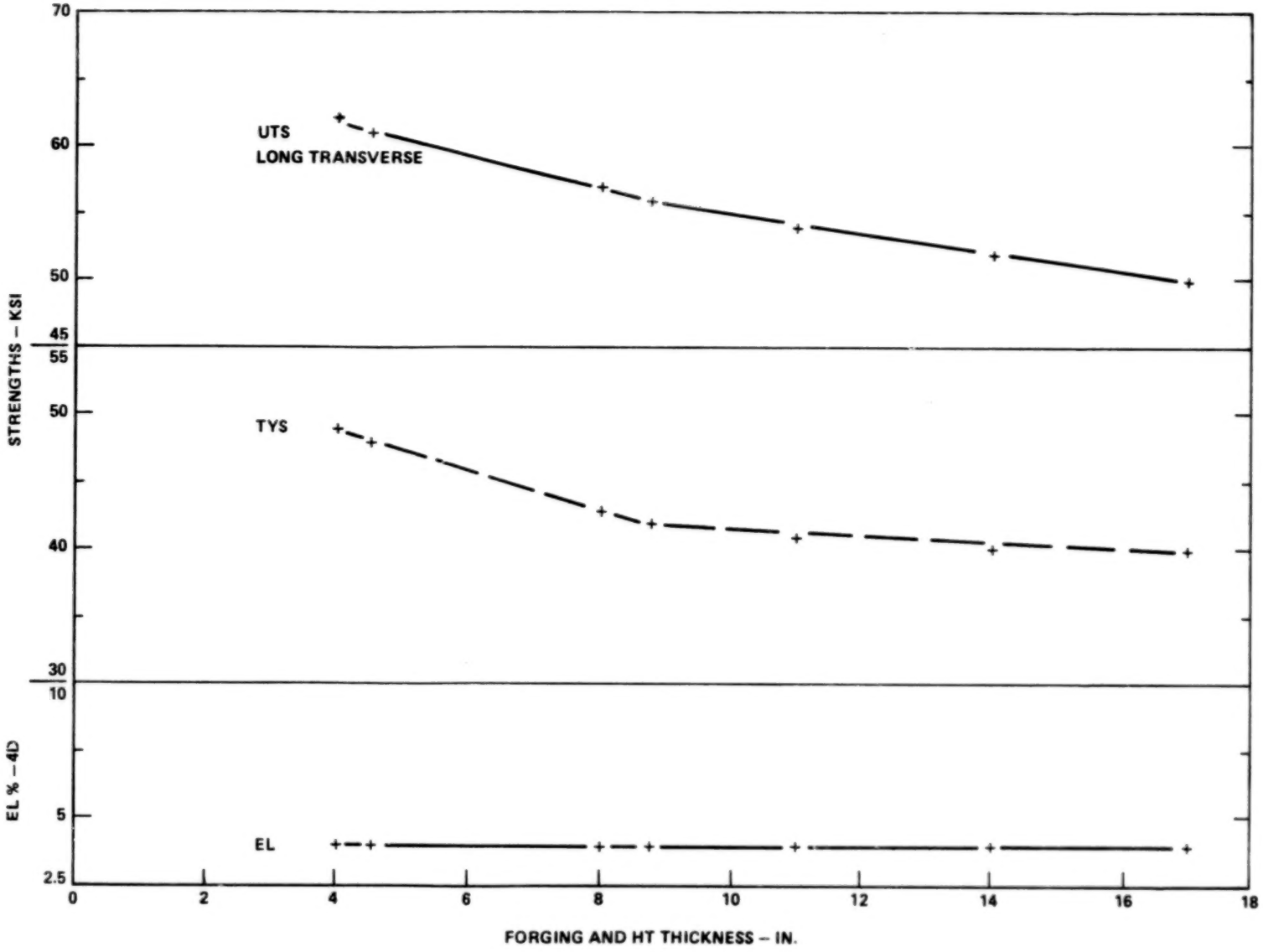


Figure 29. 2219-T852 Al hand forgings — rectangular and contour — proposed long transverse properties

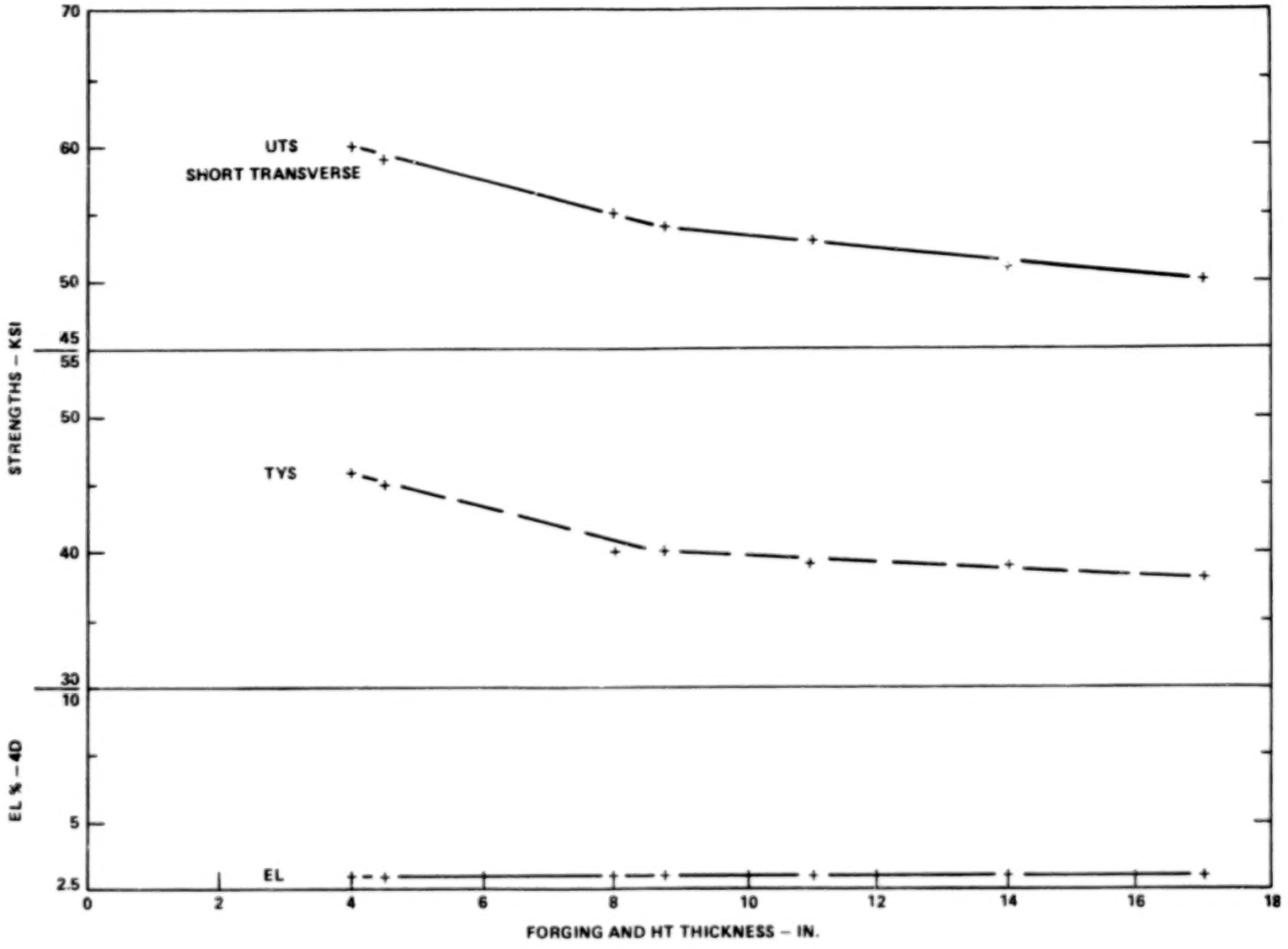


Figure 30. 2219-T852 Al hand forgings — rectangular and contour — proposed short transverse properties

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TABLE 1. LARGE HAND FORGINGS — 2219-T852
MINIMUM GUARANTEED MECHANICAL PROPERTIES

	Thickness in.	Longitudinal (L)			Long Transverse (LT)			Short Transverse (ST)			SRB Forging Identification			
		UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	Forging P/N	Cross Section t"	× w"	Test Segment No.
	Rectangular Hand Forgings													
1967	Up thru 4.0*	62	50	6	61	49	4	60	46	3	-		-	-
↓	4.1 to 6.0*	60	47	6	60	46	4	58	43	3	-		-	-
	6.1 to 8.0*	57	44	6	57	43	4	55	40	3	-		-	-
	Rectangular and Contour Hand Forgings													
1974-5	Up thru 4.0**	62	50	6	62	49	4	60	46	3	14A30400	7	× 22 1/2	1, 2 & Prolongation
	4 1/2 Contoured	61	49	6	61	48	4	59	45	3	↓ 20084	5 3/4	× 29 1/2	1-4, 10, 11 & Prolongations
	8.0 Rectangular	57	44	6	57	43	4	55	40	3	↓ 30500	8	× 11	All
	8 3/4 Contoured	55	43	6	55	42	4	53	40	3	14A30400	8 3/4	× 22 1/2	3 & 4
											14A30905	10 1/2	× 10 1/2	All (Rectangular)
	11 1/2 Contoured	52	39	6	52	38	4	50	36	3	↓ 30400	↓	× 22 1/2	5 & 6
											↓ ↓	12 1/4	× ↓	7 & 8
	14 Contoured	50	37	6	50	36	4	48	34	3	14A20084	7 1/2-14†	× 29 1/2	5 & 9
1976	↓ ↓				50	36	3				↓	14	× ↓	6-8
1974-5	17 ↓	46	33	6	46	32	4	44	30	3	14A30400	14	× 22 1/2	10 & 11
												15 3/4	×	12 & 13
											↓	16 1/4	× ↓	14 & 15 & Prolongation

*Minimum tentative guarantees.

**Federal Specification QQ-A-367H; AMS 4144A '75

†Tapered areas.

TABLE 2. FORGER TEST DATA — 2219-T852 CONTOUR HAND FORGINGS — HOLDDOWN POST — DESTRUCT TEST

Destruct Test Forging P/N 14A30400			Tensile Properties								
			Longitudinal			Long Transverse			Short Transverse		
S/N	Seg. No.	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		7	62	50	6	61	49	4	60	46	3
1	1	~7	65.2	52.1	11.0	64.4	50.5	9.0	66.2	50.9	7.0
5	↓	↓	66.4	53.3	11.5	65.4	52.3	9.5	65.0	51.8	8.5
20			64.7	51.5	11.5	63.4	52.3	7.0	64.9	51.2	6.0
Min. Gtd.		8 3/4	55	43	6	55	42	4	53	40	3
1	3	~8 3/4	64.7	49.5	11.0	64.5	49.1	7.5	65.4	50.6	7.5
5	↓	↓	64.4	50.9	12.0	63.9	49.3	10.0	64.4	50.7	8.5
20			62.9	48.9	13.0	64.2	50.0	9.0	63.7	49.0	8.0
Min. Gtd.		10 1/2-12 1/4	52	39	6	52	38	4	50	36	3
1	5	~10 1/2	62.6	48.1	9.5	62.9	47.4	7.5	62.9	48.1	8.0
5	↓	↓	61.4	48.2	11.5	62.4	47.8	8.0	60.9	47.4	7.5
20			61.3	48.1	11.5	61.6	48.1	9.0	63.4	50.1	8.0
1	7	~12 1/4	59.4	47.1	12.0	60.4	46.7	6.0	60.3	46.0	9.0
5	↓	↓	59.1	45.7	11.5	58.4	44.3	8.5	58.2	46.3	8.0
20			60.6	47.1	11.0	60.0	46.0	8.0	61.6	49.2	7.5
Min. Gtd.		14-16 3/4	46	33	6	46	32	4	44	30	3
1	11	~14	58.3	45.0	10.0	58.4	44.5	8.0	57.6	43.5	8.5
5	↓	↓	57.6	45.5	11.5	55.9	42.0	9.0	55.7	41.6	9.0
20						58.5	50.4	11.0	60.3	48.1	8.0
1	13	~15 3/4	57.0	46.3	13.0	56.9	41.9	9.0	59.8	46.5	9.0
5	↓	↓	57.1	46.6	11.0	58.6	43.5	6.5	55.1	43.6	8.0
20			56.9	43.5	13.0	57.1	45.8	8.0	60.1	48.6	8.0
1	15	~16 1/4	57.6	46.3	12.0	57.3	42.9	8.5	59.8	47.0	8.5
5	↓	↓	56.2	44.6	13.5	54.1	41.4	9.0	54.9	44.3	8.5
20			58.9	45.7	11.0	60.4	49.0	6.5	58.9	49.7	8.5

Note: All locations are ℄ t and w. 1/2" D tensile specimens

Forging and HT dimensions — ~7-16 1/4" t × ~22 1 2" w × ~100" l

TABLE 3. FORGER TEST DATA — 2219-T852 CONTOUR HAND FORGINGS — HOLDDOWN POST — PROLONGATION TEST

Prolongation Test Forging P/N 14A30400				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Fwd. Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1	1	5059201	~7	65.2	52.1	11.0	64.4	50.5	9.0	66.2	50.9	7.0
2		02		-	-	-	66.4	53.0	6.5	65.6	52.0	8.0
3		03		-	-	-	66.4	53.5	5.5	67.6	52.8	7.5
4		04		63.4	52.8	13.0	65.4	50.5	7.5	65.2	52.0	8.0
5		05		66.4	53.3	11.5	65.4	52.3	9.5	65.0	51.8	8.5
6		06		-	-	-	66.5	53.2	7.5	65.2	50.9	8.5
7		07		-	-	-	69.0	54.8	8.0	66.1	52.6	8.0
8		08		-	-	-	68.2	54.4	8.5	66.0	52.3	7.5
9		09		-	-	-	66.3	51.4	8.0	66.2	51.8	8.0
10		10		63.9	51.2	12.0	64.2	49.0	8.0	62.9	50.7	8.0
11		11		64.9	50.7	11.5	64.4	49.7	8.5	63.7	51.5	8.0
12		12		65.2	52.0	10.5	64.9	51.8	8.5	64.9	52.8	6.5
13		13		64.9	52.3	10.0	63.9	50.5	9.0	63.7	50.6	9.0
				-	-	-	-	-	-	*63.8	50.7	9.0
14		14		64.9	51.2	11.5	64.4	50.7	9.0	64.6	51.7	8.5
15		15		-	-	-	65.6	52.5	8.5	65.7	52.4	7.0
16		16		-	-	-	67.2	53.6	9.0	66.7	52.1	8.0
17		17		65.4	51.2	11.0	64.9	51.0	8.5	64.4	50.7	6.0
18		18		65.6	51.4	10.5	64.8	51.8	10.0	64.1	50.3	8.5
19		19		-	-	-	66.9	51.5	7.5	64.4	51.5	4.0
20		20		64.7	51.5	11.5	63.4	52.3	7.0	64.9	51.2	6.0
21		5063701		-	-	-	66.7	52.3	7.0	64.2	50.7	7.0
23		03		-	-	-	67.0	52.0	7.0	66.2	52.5	7.0
24		04		-	-	-	67.4	52.8	7.0	65.6	52.6	5.0
25		05		-	-	-	66.4	52.6	8.0	65.4	53.5	8.0
27		07		-	-	-	67.1	53.5	8.9	66.7	53.5	7.5
28		08		-	-	-	67.0	52.0	7.5	64.4	51.2	7 5
29		09		-	-	-	65.2	50.9	8.0	65.1	51.5	7.5
30		10		-	-	-	67.0	52.2	8.0	66.7	53.1	7.5
31		11		-	-	-	66.2	50.9	8.5	65.7	47.9	8.5
33		13		-	-	-	68.0	52.6	7.5	65.9	50.8	7.0
34		14		-	-	-	67.7	53.1	7.5	65.7	51.3	7.5
35		15		-	-	-	66.0	51.5	8.0	64.2	50.4	8.0

*Retest specimen.

TABLE 3. (Continued)

Prolongation Test Forging P/N 14A30400				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Fwd. Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
36	1	5063716	~7	-	-	-	68.0	52.3	8.5	67.0	51.8	7.0
37		17		-	-	-	65.2	52.0	6.0	65.7	52.5	6.5
38		18		-	-	-	65.7	50.9	7.0	65.1	51.5	7.0
39		19		-	-	-	66.2	51.5	8.0	64.7	49.8	7.0
40		20		-	-	-	66.7	52.0	7.5	66.3	52.5	7.0
43		5095803		-	-	-	64.7	50.6	6.5	64.2	50.6	6.5
44		04		-	-	-	64.8	50.8	6.5	63.6	50.6	7.5
45		05		-	-	-	64.7	51.3	7.0	63.1	49.3	6.5
46		06		-	-	-	65.0	50.2	8.0	64.2	50.0	8.5
47		07		-	-	-	64.4	50.9	7.5	63.5	50.4	9.0
48		08		-	-	-	65.1	50.9	7.5	64.4	50.8	8.0
49		09		-	-	-	64.6	51.2	7.5	63.9	49.8	7.5
50		10		-	-	-	66.0	51.6	7.0	66.5	52.1	7.0
51		11		-	-	-	63.9	51.0	7.5	63.2	49.9	7.5
52		12		-	-	-	66.5	52.3	7.0	65.3	53.0	5.5
53		13		-	-	-	64.8	49.9	7.0	65.1	51.9	6.0
54		14		-	-	-	65.7	51.4	7.0	66.2	51.9	7.0
55		15		-	-	-	64.1	51.2	7.5	63.5	50.5	8.5
56		16		-	-	-	65.4	50.7	7.5	64.9	51.8	6.0
57		17		-	-	-	65.8	50.9	7.5	64.9	52.0	6.5
58		18		-	-	-	65.5	51.5	7.0	65.3	52.0	6.5
59		19		-	-	-	64.2	50.7	6.5	63.9	49.7	8.5
61		21		-	-	-	64.9	51.3	7.5	63.4	51.3	6.0
1/2" D tensile ℄ t and w				Forging and HT dimensions — ~7 - 16 1/4" t × 22 1/2" w × ~100" l Prolongations aged by Forger								
Minimum Guaranteed			7	62	50	6	61	49	4	60	46	3

TABLE 3. (Continued)

Prolongation Test Forging P/N 14A30400				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Aft Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1	15	5059201	~15 3/4	57.6	46.3	12.0	57.3	42.9	8.5	59.8	47.0	8.5
2		02		-	-	-	60.4	48.4	5.5	60.4	47.9	7.0
3		03		-	-	-	66.8	53.1	7.5	64.2	54.1	6.5
4		04		59.4	46.4	12.5	57.3	44.6	8.0	59.6	45.7	8.0
5		05		56.2	44.6	13.5	54.1	41.4	9.0	54.9	44.3	8.5
6		06		-	-	-	56.7	44.3	7.0	60.9	48.9	7.5
7		07		-	-	-	64.3	50.1	5.5	62.6	49.3	8.0
8		08		-	-	-	65.1	52.0	5.5	62.8	50.7	7.5
9		09		-	-	-	61.3	50.1	5.0	60.4	48.6	8.0
10		10		60.1	48.2	9.5	56.8	45.2	7.0	57.8	45.7	8.5
11		11		58.8	46.9	10.5	56.6	45.0	7.0	58.9	46.8	8.5
12		12		58.3	46.7	11.5	56.8	43.4	8.0	58.9	46.7	8.0
13		13		58.6	44.5	12.5	56.1	43.5	7.0	57.1	45.5	9.5
				-	-	-	-	-	-	-	-	-
14		14		58.1	45.5	13.0	56.6	44.5	9.0	57.8	45.7	9.0
15		15		-	-	-	58.6	45.3	7.0	61.9	49.6	7.5
16		16		-	-	-	55.9	44.0	6.5	60.7	48.8	7.5
17		17		58.9	45.6	12.0	59.9	46.7	7.5	61.9	46.7	8.5
18		18		61.3	48.1	10.5	62.0	48.9	7.0	59.8	50.3	8.0
19		19		-	-	-	68.4	53.5	7.5	66.0	51.9	7.5
20		20		58.9	45.7	11.0	60.4	49.0	6.5	58.9	49.7	8.5
21		5063701		-	-	-	65.7	50.3	8.0	65.9	51.8	8.0
23		03		-	-	-	59.9	47.1	6.5	59.6	47.4	8.0
24		04		-	-	-	60.4	47.8	7.0	59.6	47.9	7.5
25		05		-	-	-	60.7	52.6	6.0	60.6	53.1	8.0
27		07		-	-	-	59.4	45.9	7.0	58.9	46.9	7.0
28		08		-	-	-	63.9	49.2	8.0	63.7	49.3	9.0
29		09		-	-	-	59.9	46.7	6.0	58.8	47.9	7.0
30		10		-	-	-	59.1	45.5	7.0	58.3	46.2	7.5
31		11		-	-	-	61.6	46.9	7.0	59.6	51.5	7.5
33		13		-	-	-	64.7	49.5	8.5	64.7	50.3	8.5
34		14		-	-	-	66.2	50.2	7.0	66.4	51.3	8.0
35		15		-	-	-	66.5	51.0	8.5	65.2	51.2	7.5

TABLE 3. (Concluded)

Prolongation Test Forging No. 14A30400				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Aft Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
36	15	5063716	~15 3/4	-	-	-	60.9	49.0	8.0	60.2	48.4	7.5
37		17		-	-	-	62.1	50.6	6.0	60.6	51.7	6.5
38		18		-	-	-	61.1	47.4	6.5	60.1	46.9	8.0
39		19		-	-	-	65.4	49.6	8.0	63.9	49.7	6.0
40		20		-	-	-	60.9	46.6	7.0	59.6	47.2	7.5
43		5095803		-	-	-	59.1	46.0	5.5	57.3	44.7	8.5
44		04		-	-	-	59.1	46.5	6.0	57.1	43.5	9.0
45		05		-	-	-	60.8	48.2	5.5	60.5	46.8	7.0
46		06		-	-	-	59.2	45.3	6.5	56.7	44.5	9.0
47		07		-	-	-	57.6	44.4	5.5	56.2	43.8	9.5
48		08		-	-	-	59.0	45.7	6.5	56.8	43.8	9.5
49		09		-	-	-	59.1	45.5	6.5	57.3	44.6	9.0
50		10		-	-	-	64.9	49.1	7.0	63.1	49.4	7.5
51		11		-	-	-	59.2	46.8	6.5	57.0	44.0	8.5
52		12		-	-	-	60.4	47.3	5.5	64.1	49.9	8.5
53		13		-	-	-	57.4	43.2	7.5	62.9	49.4	7.5
54		14		-	-	-	64.6	49.9	6.0	63.1	49.9	7.5
55		15		-	-	-	60.8	46.8	6.5	58.7	46.0	8.5
56		16		-	-	-	62.9	48.7	6.0	63.0	49.7	7.5
57		17		-	-	-	61.3	47.1	7.0	65.6	51.6	7.5
58		18		-	-	-	61.9	47.9	6.5	62.0	49.0	7.5
59		19		-	-	-	59.2	46.0	5.0	57.5	44.5	9.5
61		21		-	-	-	64.1	50.9	8.0	61.9	48.2	5.0
1/2" D tensile C_L t and w				Forging and HT dimensions — ~7 - 16 1/4" t × ~22 1/2" w × ~100" l Prolongations aged by Forger								
Minimum Guaranteed			15 3/4	46	33	6	46	32	4	44	30	3

TABLE 4. MDAC TEST DATA – 2219-T852 CONTOUR HAND FO

Forging P/N 14A30400[1]			Tensile Properties											
S/N 1			1/2" D Specimens											
			Longitudinal				Long Transverse				Short Transverse			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %
2	$\frac{1}{4}$ L	~7	-	-	-	-	-	-	-	-	*66.4	52.1	7.0	8.3
											66.7	52.5	7.5	8.2
											-	-	-	-
											66.5	52.3	7.2	8.2
4		~8 3/4	-	-	-	-	-	-	-	-	*63.7	49.1	7.0	9.0
											64.5	49.6	7.0	7.4
											-	-	-	-
											64.1	49.3	7.0	8.2
6		~10 1/2	-	-	-	-	-	-	-	-	*61.2	47.2	8.0	13.6
											61.6	47.2	8.5	10.9
											-	-	-	-
											61.4	47.2	8.2	12.2
8		~12 1/4	-	-	-	-	-	-	-	-	*59.5	45.5	8.5	13.2
											60.1	45.7	8.0	12.4
											-	-	-	-
											59.8	45.6	8.2	12.8
10		~14	-	-	-	-	-	-	-	-	*57.7	45.0	8.5	13.2
											58.0	44.0	8.5	13.2
											-	-	-	-
											57.8	44.5	8.5	13.2

See Page 43 for Notes

Stress Corrosion — 3.5% NaCl Alt. Imm.						
Short Transverse (℄ t and w; 1/4" D X 1" GL)						
Tensile Blanks			Unstressed		Stressed[2]	
TYS ksi	EL %	RA %	UTS	EL	UTS	EL
			% Change in 30 Days			
51.5	7.0	9.3	-21.5	-71.4	-20.2	-71.4
51.3	7.0	9.3	-20.2	-64.3	-21.1	-71.4
51.3	7.0	9.4	-21.2	-71.4	-27.9	-85.7
51.4	7.0	9.3	-20.9	-68.5	-23.0	-75.7
48.9	8.0	12.4	-22.0	-74.0	-18.8	-74.0
48.9	8.0	13.1	-21.4	-74.0	-21.7	-74.0
48.9	7.0	12.1	-20.1	-74.0	-19.5	-67.5
48.9	7.7	11.9	-21.2	-74.0	-19.9	-71.4
49.3	5.7	8.1	-24.6	-72.7	— FH —	
45.2	7.0	8.7	-21.5	-86.1	-18.4	-86.1
45.6	7.5	11.0	-16.4	-79.2	-17.1	-93.1
46.1	7.0	8.7	-13.7	-79.2	-17.1	-79.2
45.6	7.2	9.5	-17.2	-81.9	-17.5	-86.1
44.5	8.0	10.2	- 8.1	-63.4	-11.0	-69.5
44.6	8.0	11.6	-10.7	-69.5	-10.2	-69.5
44.7	8.5	15.4	-10.0	-69.5	-16.8	-81.7
44.6	8.2	12.4	- 9.6	-67.1	-12.7	-73.2
43.2	9.0	12.3	-13.1	-77.8	-13.5	-66.7
43.8	9.0	11.6	-13.6	-72.2	-16.1	-77.8
43.6	9.0	13.1	-20.0	-83.3	-11.1	-77.8
43.5	9.0	12.3	-15.5	-77.8	-13.5	-74.4
49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4
49.3	5.5	8.6	-26.0	-91.2	-26.3	-100
48.9	5.0	6.4	-27.3	-100	-29.2	-100
49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7

Forging P/N 14A30400(1)			Tensile Properties							
			1/2" D Specimens							
S/N 1			Longitudinal				Long Transverse			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi
12	℄; E(4)	~15 3/4	*57.7	45.0	11.5	22.3	*57.4	44.0	7.0	9.4	-
	℄		58.6	45.3	10.0	23.7	57.9	43.8	6.5	10.5	*56.7
			--	-	-	-	-	-	-	-	56.7
	℄; E(4)		58.1	44.8	11.5	26.0	57.2	43.1	6.5	10.9	-
			58.1	45.0	11.0	24.0	57.5	43.6	6.7	10.3	56.7
14	℄	~16 1/4	57.8	44.7	11.0	21.9	-	-	-	-	57.7
			58.5	45.5	11.0	21.9	-	-	-	-	56.5
			58.1	45.1	11.0	21.9					57.1
2	Min. Gtd.	~7	62	50	6	-	61	49	4	-	60
4		~8 3/4	55	43	6	-	55	42	4	-	53
6&8		10 1/2-12 3/4	52	39	6	-	52	38	4	-	50
10,12&14		14-16 1/4	46	33	6	-	46	32	4	-	44

Notes:

(1) Forged and HT dimensions ~7-16 1/4" t × ~22 1/2" w × ~100" l.
Alcoa cut into segments before aged.

(2) Stressed to 75% of TYS.

(3) Standard — specimens from 2219-T851 plate 6 1/8" t exposed simultaneously.

(4) Specimen 1 1/2" from outside edge of width, all others are ℄ width and thickness.

*Stress-strain curves available.

FH - Failed in handling during removal from stressing fixture.

Toughness	Stress Corrosion — 3.5% NaCl Alt. Imm.							
t Tension	Short Transverse (℄ t and w; 1/4" D X 1" GL)							
ksi $\sqrt{in.}$	Tensile Blanks				Unstressed		Stressed[2]	
(L-S)	UTS ksi	TYS ksi	EL %	RA %	UTS	EL	UTS	EL
					% Change in 30 Days			
-	56.4	43.2	8.0	11.6	-19.7	-88.0	-13.7	-81.9
-	56.0	42.8	8.0	10.9	-13.7	-75.9	-15.4	-81.9
-	56.6	43.0	9.0	13.8	-12.4	-75.9	-16.3	-88.0
-	56.3	43.0	8.3	12.1	-15.6	-79.5	-15.3	-83.9
	(3) 62.7	49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7
(35.36)[B] [1.170] (35.48)[B] [1.183]	-	-	-	-	-	-	-	-

imens
pecimens
n parentheses
n brackets

TABLE 4. (Continued)

Forging P/N 14A30400(1)			Tensile Properties												Fracture Toughness	
			1/2" D Specimens												Compact Tension K_{1c} – ksi $\sqrt{in.}$	
S/N 5			Longitudinal				Long Transverse				Short Transverse					
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)
2	$\mathbb{C}_L$	~7	-	-	-	-	-	-	-	-	65.6	51.7	5.5	9.3	(33.12)(A) [0.983]	-
											65.5	51.8	6.5	10.2	-	-
											65.5	51.7	6.0	9.7		
4		~8 3/4	-	-	-	-	-	-	-	-	63.6	49.5	7.5	12.1	23.07(B)	-
											63.7	49.8	7.0	10.5	-	
											63.6	49.7	7.2	11.3		
6		~10 1/2	-	-	-	-	-	-	-	-	60.1	46.6	7.0	10.6	35.32(B)	
											60.2	46.8	7.0	10.1	-	-
											60.1	46.7	7.0	10.3		
8	$\mathbb{C}_L$	~12 1/4	-	-	-	-	-	-	-	-	57.8	44.4	6.0	12.3	(32.07)(B) [1.036]	-
											57.6	44.7	7.0	10.9	-	-
											57.7	44.5	6.5	11.6		
10		~14	-	-	-	-	-	-	-	-	56.2	41.5	6.5	12.8	(34.44)(B) [1.202]	-
											56.2	42.8	6.5	12.0	-	-
											56.2	42.1	6.5	12.4		
12	$\mathbb{C}_L$; E(4)	~15 3/4	56.1	43.6	11.5	26.2	56.0	43.7	5.0	7.4	-	-	-	-	-	-
	$\mathbb{C}_L$		56.4	44.3	12.0	25.7	55.9	42.9	5.0	8.7	54.7	41.5	8.5	13.2	(33.04)(B) [0.993]	-
			-	-	-	-	-	-	-	-	54.7	41.6	9.0	12.5	-	-
	$\mathbb{C}_L$; E(4)		55.9	43.7	11.5	24.4	55.6	42.7	5.5	9.4	-	-	-	-	-	-
			56.1	43.9	11.7	25.4	55.8	43.1	5.2	8.5	54.7	41.5	8.7	12.8		
14	$\mathbb{C}_L$	~16 1/4	55.5	43.4	10.5	26.4	-	-	-	-	55.6	43.6	8.0	12.3	26.28(B)	(31.23)(B) [1.001]
			56.5	43.2	11.0	25.8					54.9	42.8	8.0	12.4	24.02(B)	(32.80)(B) [1.084]
			56.0	43.3	10.7	26.1					55.2	43.2	8.0	12.4		

See Page 43 for Notes

TABLE 4. (Concluded)

Forging P/N 14A30400(1)			Tensile Properties												Fracture Toughness	
			1/2" D Specimens												Compact Tension K_{1c} – ksi $\sqrt{in.}$	
S/N 20			Longitudinal				Long Transverse				Short Transverse					
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)
2	$\mathbb{C}_L$	~7	-	-	-	-	-	-	-	-	64.4	51.0	6.0	8.6	(23.76)(A) [0.729]	-
											64.4	50.9	6.5	10.5	-	-
											64.4	51.0	6.3	9.6		
4		~8 3/4	-	-	-	-	-	-	-	-	62.6	48.9	6.5	10.5	23.68(A)	-
											62.6	49.0	6.5	8.6	-	-
											62.6	49.0	6.5	9.6		
6		~10 1/2	-	-	-	-	-	-	-	-	60.2	46.8	6.0	9.7	23.61(A)	-
											60.1	46.8	7.0	10.5	-	-
											60.2	46.8	6.5	10.1		
8	$\mathbb{C}_L$	~12 1/4	-	-	-	-	-	-	-	-	59.1	45.1	7.0	10.6	23.66(A)	-
											59.0	45.5	7.0	11.3	-	-
											59.0	45.3	7.0	11.0		
10		~14	-	-	-	-	-	-	-	-	57.6	45.0	7.0	11.7	22.75(A)	-
											57.6	44.4	7.0	10.9	-	-
											57.6	44.7	7.0	11.3		
12	$\mathbb{C}_L$; E(4)	~15 3/4	57.3	45.3	9.5	25.5	57.1	44.2	6.5	10.9	-	-	-	-	-	-
	$\mathbb{C}_L$		58.0	46.0	9.5	25.1	57.2	44.4	6.0	9.4	56.2	43.8	7.5	13.9	22.73(A)	-
			-	-	-	-	-	-	-	-	56.2	43.3	7.5	12.3	-	-
	$\mathbb{C}_L$; E(4)		57.1	45.0	10.0	26.1	57.2	44.9	6.5	7.9	-	-	-	-	-	-
			57.5	45.4	9.8	25.6	57.2	44.5	6.3	9.4	56.2	43.6	7.5	13.1		
14	$\mathbb{C}_L$	~16 1/4	56.8	44.1	10.0	25.0	-	-	-	-	57.0	44.5	8.0	14.7	23.09(A)	(30.29)(A) [1.255]
			57.3	45.0	10.0	25.5					56.0	41.3	6.5	11.3	22.65(A)	(29.17)(A) [1.159]
			57.1	44.6	10.0	25.2					56.5	42.9	7.2	13.0		

See Page 43 for Notes

TABLE 5. 2219-T852 CONTOUR HAND FORGING – DETAILED SUMMARY
COMBINED TESTS – HOLDDOWN POST – 14A30400

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL % / 4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL % / 4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL % / 4 D	Short Transverse RA %
Forger Min. Gtd.		7	62	50	6	-	61	49	4	-	60	46	3	-
3 destruct	A	~7	(3) 64.7-66.4	51.5-53.3	11.0-11.5	-	(3) 63.4-65.4	50.5-52.3	7.0-9.5	-	(3) 64.9-66.2	50.9-51.8	6.0-8.5	-
↓	M		-	-	-	-	-	-	-	-	(9) 64.4-66.7	50.9-52.5	5.1-7.5	8.3-10.5
*1 x-skirt	M		(3) 63.5-63.7	49.9-50.3	9.5-10.0	27.0-27.7	-	-	-	-	-	-	-	-
52 Prol.	A		(8) 63.4-65.6	50.7-52.8	10.0-13.0	-	(52) 63.9-69.0	49.0-54.8	5.5-10.0	-	(53) 62.9-67.6	47.9-53.5	4.0-9.0	-
*1 x-Prol.	M		-	-	-	-	(3) 67.5-68.2	53.3-54.6	4.5-5.0	4.4-8.3	(3) 68.0-68.4	53.3-54.0	5.5-6.0	6.7-8.2
*4 P-Prol.	M		-	-	-	-	(4) 62.4-65.3	50.7-51.6	5.5-7.0	6.7-9.8	(4) 61.4-65.8	49.2-52.9	5.0-7.0	6.0-9.8
Forger Min. Gtd.		8 3/4	55	43	6	-	55	42	4	-	53	40	3	-
3 destruct	A	~8 3/4	(3) 62.9-64.7	48.9-50.9	11.0-13.0	-	(3) 63.9-64.5	49.1-50.0	7.5-10.0	-	(3) 63.7-65.4	49.0-50.7	7.5-8.5	-
↓	M		-	-	-	-	-	-	-	-	(9) 62.6-64.5	48.9-49.8	6.5-7.5	7.4-12.1
Forger Min. Gtd.		10 1/2-12 1/4	52	39	6	-	52	38	4	-	50	36	3	-
3 destruct	A	~10 1/2	(3) 61.3-62.6	48.1-48.2	9.5-11.5	-	(3) 61.6-62.9	47.1-48.1	7.5-9.0	-	(3) 60.9-63.4	47.4-50.1	7.5-8.5	-
↓	M		-	-	-	-	-	-	-	-	(9) 59.8-61.6	45.2-47.2	6.0-8.5	-
3 destruct	A	~12 1/4	(3) 59.1-60.6	45.7-47.1	11.0-12.0	-	(3) 58.4-60.4	44.3-46.7	6.0-8.5	-	(3) 58.2-61.6	43.0-49.2	7.5-9.0	-
↓	M		-	-	-	-	-	-	-	-	(9) 57.6-59.5	44.0-45.5	6.0-8.5	10.2-15.4
*1 x-skirt	M		-	-	-	-	-	-	-	-	(3) 58.6-59.8	45.2-45.8	6.5-7.5	6.7-10.4

TABLE 5. (Concluded)

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL % / 4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL % / 4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL % / 4 D	Short Transverse RA %
Forger Min. Gtd.		14-16 1/4	46	33	6	-	46	32	4	-	44	30	3	-
3 destruct A	C/L	~14	(3) 57.6-58.3	45.0-45.5	10.0-11.5	-	(3) 55.9-58.5	42.0-50.4	8.0-11.0	-	(3) 55.7-60.3	41.6-48.1	8.0-9.0	-
M			-	-	-	-	-	-	-	-	(9) 56.2-58.6	41.5-45.0	6.5-9.0	10.9-13.2
3 destruct A	C/L	~15 3/4	(3) 56.9-57.1	43.5-46.6	11.0-13.0	-	(3) 56.9-58.6	41.9-45.8	6.5-9.0	-	(3) 55.1-60.1	43.6-48.6	8.0-9.0	-
M			(3) 56.4-58.6	44.3-46.0	9.5-12.0	23.7-25.7	(3) 55.9-57.9	42.9-44.4	5.0-6.5	8.7-10.5	(9) 54.7-56.7	41.5-43.8	7.0-9.0	10.9-13.9
M	C/L; E		(6) 55.9-58.1	43.6-45.3	9.5-11.5	22.3-26.2	(6) 55.6-57.4	42.7-44.9	5.0-7.0	7.4-10.9	-	-	-	-
3 destruct A	C/L	~16 1/4	(3) 56.2-58.9	44.6-46.3	11.0-13.5	-	(3) 54.1-60.4	41.4-49.0	6.5-9.0	-	(3) 54.9-59.8	44.3-49.7	8.5-8.5	-
M			(6) 55.5-58.5	43.2-45.5	10.0-11.0	21.9-26.4	-	-	-	-	(9) 54.9-57.7	41.3-44.9	6.5-8.5	11.3-14.7
*1 x-skirt M			-	-	-	-	(3) 55.8-57.8	42.6-45.3	5.5-7.0	7.8-15.0	-	-	-	-
52 Prol. A			(8) 58.1-61.3	44.5-47.2	9.5-12.5	-	(52) 55.9-68.4	43.2-53.5	5.0-9.0	-	(52) 56.2-66.0	43.5-54.1	5.0-9.5	-
*1 x-Prol. M			-	-	-	-	(3) 58.8-59.1	46.0-46.2	5.5-6.5	8.2-8.9	(3) 56.7-58.0	45.1-46.3	6.5-7.5	9.5-11.6
*4 P-Prol. M			-	-	-	-	(4) 54.1-56.5	41.8-43.3	4.5-6.5	4.7-10.6	(4) 53.8-56.3	43.5-45.8	6.5-8.0	9.4-13.5

A = Alcoa test
M = MDAC test
* = MDAC aged; all others were forger aged
x = simulation age
P = production age
skirt = MDAC 1/4 skirt, destruct test
Prol. = prolongation from end of forging
◯ = No. of 1/2" and 1/4" D tensile specimens tested, min. to max. values obtained

TABLE 6. 2219-T852 CONTOUR HAND FORGING — CONDENSED SUMMARY
COMBINED TESTS — HOLDDOWN POST — 14A30400

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL %/4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL %/4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL %/4 D	Short Transverse RA %
Forger Min. Gtd.		7	62	50	6	-	61	49	4	-	60	46	3	-
55(1)	CL	~7	(11) 63.4-66.4	50.7-53.3	10.0-13.0	-	(62) 62.4-69.0	49.0-54.8	4.5-10.0 (7)	4.4-9.8	(72) 61.4-68.4	47.9-54.0	4.0-9.0	(16) 6.0-10.5
1(2)			(3) 63.5-63.7	49.9-50.3	9.5-10.0	(3) 27.0-27.7	-	-	-	-	-	-	-	-
Forger Min. Gtd.		8 3/4	55	43	6	-	55	42	4	-	53	40	3	-
3(3)	CL	~8 3/4	(3) 62.9-64.7	48.9-50.9	11.0-13.0	-	(3) 63.9-64.5	49.1-50.0	7.5-10.0	-	(12) 62.6-65.4	48.9-50.7	6.5-8.5	(9) 7.4-13.1
Forger Min. Gtd		10 1/2-12 1/4	52	39	6	-	52	38	4	-	50	36	3	-
3(3)	CL	~10 1/2	(3) 61.3-61.6	48.1-48.2	9.5-11.5	-	(3) 61.6-62.9	47.4-48.1	7.5-9.0	-	(12) 59.8-63.4	45.2-50.1	6.0-8.5	(9) 8.7-13.6
3(3)		~12 1/4	(3) 59.1-60.6	45.7-47.1	11.0-12.0	-	(3) 58.4-60.4	44.3-46.7	6.0-8.5	-	(12) 57.6-61.6	44.0-49.2	6.0-9.0	(9) 10.2-15.4
1(2)			-	-	-	-	-	-	-	-	(3) 58.6-59.8	45.2-45.8	5.5-7.5	(3) 6.7-10.4
Forger Min. Gtd.		14-16 1/4	46	33	6	-	46	32	4	-	44	33	3	-
3(3)	CL	~14	(2) 57.6-58.3	45.0-45.5	10.0-11.5	-	(3) 56.9-58.5	42.0-42.4	8.0-11.0	-	(12) 55.7-60.3	41.5-48.1	6.5-9.0	(9) 10.9-13.2
3(3)		~15 3/4	(12) 55.9-58.6	43.5-46.6	9.5-13.0	(9) 22.3-26.2	(12) 55.6-58.6	41.9-45.8	5.0-9.0 (9)	7.4-10.9	(12) 54.7-60.1	41.5-48.6	7.0-9.0	(9) 10.9-13.9
55(1)		~16 1/4	(17) 55.5-61.3	43.2-48.2	9.5-13.5	(6) 21.9-26.4	(62) 54.1-68.4	41.4-53.5	4.5-9.0 (7)	4.7-10.6	(71) 53.8-66.0	41.3-54.1	5.0-9.5	(16) 9.4-14.7
1(2)			-	-	-	-	(3) 55.8-57.8	42.6-45.3	5.5-7.5 (3)	7.8-15.0	-	-	-	-

(1) 3 destruct +52 prolongation tests
(2) 1 destruct from MDAC aged 1/4 skirt
(3) 3 destruct
◯ = No. of 1/2" and 1/4" D specimens tested; min. to max. values obtained

Forged and HT dimensions — ~7-16 1/4" t × ~22 1/2" w × ~100" l

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TABLE 7. FORGER DATA — 2219-T852 CONTOUR HAND FORGINGS — THRUST POST — DESTRUCT TEST

Forging P/N 14A20084			Tensile Properties — Longitudinal								
			S/N 1			S/N 13			S/N 19		
Seg. No.	Loc. (Fig. 5)	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		5 3/4				61	49	6			
11	t/2; w/2	5 3/4	63.6	51.3	12.0	66.7	51.5	10.5	63.3	50.2	11.0
1			64.2	52.0	13.0	67.9	50.6	7.5	63.7	50.0	10.5
3A	w/7		62.4	50.5	13.0	67.1	51.7	11.5	62.7	49.7	10.5
B	w/2		62.2	49.9	12.0	69.0	52.6	11.0	63.2	50.0	10.5
C	w/7		62.6	50.7	13.0	67.1	51.6	11.0	63.5	50.2	11.0
Min. Gtd.		7 1/2-12				50	37	6			
9A	t/4 top; w/4	7 1/2	63.5	48.9	11.0	66.0	50.6	10.5	60.1	46.5	10.5
B	w/2		63.1	48.1	11.0	65.3	50.0	10.5	61.1	47.5	11.5
C	w/4		63.4	49.3	11.0	66.0	50.5	11.0	61.9	48.7	10.5
Min. Gtd.		14				50	37	6			
5A	t/4 top; w/4	14	-	-	-	-	-	-	-	-	-
B	w/2		-	-	-	-	-	-	-	-	-
C	w/4		-	-	-	-	-	-	-	-	-
A	bottom; w/4		-	-	-	-	-	-	-	-	-
B	w/2		-	-	-	-	-	-	-	-	-
C	w/4		-	-	-	-	-	-	-	-	-
7A	top; w/4		58.8	46.5	10.5	62.2	48.9	9.0	59.9	47.2	9.5
B	w/2		57.5	44.5	11.5	59.6	45.3	11.5	57.1	44.6	10.5
C	w/4		60.3	47.0	11.0	64.1	49.3	9.5	58.3	45.7	9.5
A	bottom; w/4		60.5	47.5	11.0	63.8	49.8	9.5	57.6	45.7	11.0
B	w/2		59.3	46.0	11.0	63.7	48.7	11.0	48.3	45.5	10.0
C	w/4		61.3	48.1	10.5	66.7	51.8	9.5	60.6	48.0	10.0
1/2" D tensile specimens forging and HT dimensions — ~5 3/4 - 14" t × ~29 1/2" w × ~115 1/2" l											
Min. Gtd. (Forger)		5 3/4	61	49	6						
		7 1/2-12	50	37	6						
		14	50	37	6						

TABLE 7. (Continued)

Destruct Test Forging P/N 14A20084			Tensile Properties — Long Transverse								
			S/N 1			S/N 13			S/N 19		
Seg. No.	Loc. (Fig. 5)	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		5 3/4				61	48	4			
11	t/2; w/2	5 3/4	65.9	51.5	9.0	67.8	50.6	9.5	63.7	49.7	8.5
1			64.9	51.4	9.0	66.9	51.3	11.0	64.4	50.7	9.0
3A	w/7		63.8	51.5	8.5	65.1	51.3	5.5	62.6	49.0	7.5
B	w/2		63.8	50.6	8.5	66.3	49.5	8.5	62.4	49.0	7.5
C	w/7		63.0	50.4	8.5	67.1	51.7	7.0	61.8	48.5	7.5
Min. Gtd.		7 1/2-12				50	36	4			
9A	t/4 top; w/4	7 1/2	61.6	49.1	6.0	66.2	50.7	6.5	59.9	46.5	8.0
B	w/2		62.8	48.6	6.5	66.0	49.5	9.0	59.8	45.5	8.5
C	w/4		61.6	49.3	5.0	66.6	50.8	7.0	60.9	47.7	6.0
Min. Gtd.		14				50	36	4			
5A	t/4 top; w/4	14	58.4	47.3	7.0	64.5	51.9	5.0	57.6	44.5	7.5
B	w/2		57.1	46.9	5.0	63.2	47.1	6.0	59.4	45.5	7.5
C	w/4		58.6	48.1	6.0	64.0	52.5	5.0	61.4	47.2	7.5
A	bottom; w/4		60.1	46.9	7.0	62.9	51.6	5.0	53.9	43.0	6.0
B	w/2		59.6	47.1	7.5	59.8	44.2	7.5	54.6	42.4	6.0
C	w/4		60.4	47.2	7.5	62.2	51.9	4.5	53.2	43.6	4.0
Min. Gtd.		14				50	36	3			
7A	t/4 top; w/4	14	53.2	48.6	4.0	70.6	54.7	8.0	52.0	44.6	3.0
			-	-	-	-	-	-	*51.0	45.2	3.0
			-	-	-	-	-	-	*50.3	45.0	3.0
B	w/2		57.1	46.0	6.0	62.7	46.5	8.0	53.6	43.5	4.5
C	w/4		58.4	47.4	6.0	59.5	49.2	3.5	50.2	44.5	3.0
			-	-	-	*58.8	44.0	8.0	*50.0	44.5	2.5
			-	-	-	*57.8	43.1	8.0	*50.3	45.5	3.0
A	bottom; w/4		53.2	46.5	4.0	66.4	52.3	5.0	56.8	46.3	4.5
B	w/2		56.6	45.0	6.0	60.9	49.9	8.5	56.9	45.8	4.5
C	w/4		55.8	46.0	5.0	58.9	49.3	3.5	50.3	46.6	3.5
			-	-	-	*56.6	49.2	3.0	*51.4	45.5	3.0
			-	-	-	*56.0	48.5	3.0	*50.5	44.7	3.0
1/2" D tensile specimens. Forging and HT dimensions — ~5 3/4 - 14" t × ~29 1/2" w × ~115 1/2" l											
Min. Gtd. (Forger)		5 3/4	61	48	4						
		7 1/2-12	50	36	4						
		14	50	36	4 seg. 5 3 seg. 6-8						

*Retest specimens.

TABLE 7. (Concluded)

TABLE 7. (Concluded)

Destruct Test Forging P/N 14A20084			Tensile Properties — Short Transverse								
			S/N 1			S/N 13			S/N 19		
Seg. No.	Loc. (Fig. 5)	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
Min. Gtd.		5 3/4				59	45	3			
11	t/2; w/2	5 3/4	64.9	51.5	7.0	68.0	53.3	7.0	62.4	48.9	6.5
1			64.6	51.0	8.5	67.3	52.8	5.5	62.9	50.5	8.0
3A	w/7		63.6	51.1	8.5	66.0	51.8	4.5	62.0	49.5	8.0
B	w/2		64.5	51.5	7.5	67.7	52.4	7.0	61.5	49.0	7.5
C	w/7		63.5	50.8	7.5	68.3	54.7	6.0	61.5	49.2	6.5
Min. Gtd.		7 1/2-12				48	34	3			
9A	t/4 top; w/4	7 1/2	63.0	49.1	6.0	65.8	51.0	7.5	58.1	45.5	6.5
B	w/2		62.6	49.6	6.0	66.2	50.7	7.0	57.8	44.6	6.0
C	w 4		64.5	50.7	9.0	66.0	50.8	6.0	59.6	47.0	8.0
Min. Gtd.		14				48	34	3			
5A	t/4 top; w/4	14	57.7	47.0	5.5	64.3	51.0	6.0	57.4	46.5	6.0
B	w/2		58.6	47.4	7.0	60.4	46.0	7.0	57.1	45.5	7.0
C	w/4		56.0	46.4	5.5	63.5	50.5	5.0	56.6	44.5	7.0
A	bottom; w/4		59.9	47.4	7.5	62.4	48.8	6.5	56.8	44.0	7.0
B	w/2		58.6	46.1	7.5	59.5	44.5	7.5	56.6	43.5	8.0
C	w/4		58.3	45.4	7.0	62.6	49.5	5.5	56.1	43.5	7.5
7A	top; w/4		58.3	45.8	7.0	59.6	48.4	5.0	55.1	45.5	5.0
B	w/2		56.7	44.5	8.0	58.7	43.8	7.5	55.1	43.5	7.0
C	w/4		58.0	46.0	6.5	60.0	49.0	4.0	54.1	46.5	5.0
A	bottom; w/4		58.1	45.8	6.5	58.2	49.1	4.0	54.8	45.5	5.0
B	w/2		57.3	44.0	7.0	59.8	46.2	6.5	54.9	43.5	5.5
C	w/4		58.9	47.0	6.0	60.1	49.3	4.0	56.2	46.0	5.5
Forging and HT dimensions — ~5 3/4 - 14" t × ~29 1/2" w × ~115 1/2" l 1/2" D tensile specimens											
Min. Gtd. (Forger)		5 3/4	59	45	3						
		7 1/2-12	48	34	3						
		14	48	34	3						

TABLE 8. FORGER DATA — 2219-T852 CONTOUR HAND FORGINGS — THRUST POST — PROLONGATION TEST

Prolongation Tests Forging P/N 14A20084				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1	1	5059501	5-3/4	64.2	52.0	13.0	64.9	51.4	9.0	64.6	51.0	8.5
	11			63.6	51.3	12.0	65.9	51.5	9.0	64.9	51.5	7.5
2	1	02		-	-	-	65.5	50.9	8.5	64.4	50.9	6.5
	11			-	-	-	67.2	52.0	7.0	65.7	51.5	7.0
3	1	03		64.9	49.7	10.5	62.7	48.1	8.5	62.7	48.6	7.0
	11			63.4	49.2	12.0	64.5	48.0	8.5	65.0	50.3	7.5
				*65.0	49.9	12.5	-	-	-	-	-	-
4	1	04		62.9	49.0	12.5	63.8	48.8	9.5	63.7	49.8	7.5
	11			63.9	49.0	12.5	64.4	49.1	9.5	63.9	49.7	9.0
5	1	05		63.2	49.3	11.0	63.7	49.0	10.0	61.9	48.2	9.0
				-	-	-	*64.9	50.2	10.0	-	-	-
	11			63.7	49.2	11.5	63.7	48.2	10.0	62.6	48.7	8.5
				-	-	-	*63.1	48.2	10.0	-	-	-
6	1	06		-	-	-	64.8	49.6	8.5	63.0	49.0	7.5
	11			-	-	-	64.8	50.1	9.0	62.6	48.9	8.0
7	1	07		-	-	-	66.5	51.1	8.5	63.9	49.9	7.5
	11			-	-	-	65.1	49.9	8.5	63.6	49.4	7.5
8	1	08		-	-	-	66.1	50.7	8.5	65.2	50.7	8.0
	11			-	-	-	64.4	49.7	9.0	63.2	49.2	7.5
9	1	09		66.4	52.3	11.5	65.7	51.5	8.5	65.6	51.2	9.5
	11			66.4	56.3	12.0	65.7	50.3	9.0	65.8	51.8	8.0
10	1	10		-	-	-	67.2	52.5	7.0	67.2	52.2	7.0
	11			-	-	-	66.7	52.7	7.0	66.3	52.0	7.0
11	1	11		66.5	51.8	12.0	67.2	52.6	8.5	67.5	53.3	8.5
	11			67.2	52.0	12.0	67.8	52.0	8.0	66.2	53.0	6.5
12	1	12		-	-	-	64.9	49.2	9.0	62.9	48.1	7.5
				-	-	-	*65.1	49.4	9.0	-	-	-
	11			-	-	-	65.1	49.6	9.5	64.9	49.4	8.5
13	1	13		67.9	50.6	7.5	66.9	51.3	11.0	67.3	52.8	5.5
	11			66.7	51.5	10.5	67.8	50.6	9.5	68.0	53.3	7.0

TABLE 8. (Concluded)

Prolongation Tests Forging P/N 14A20084				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
14	1	5059514	5-3/4	67.2	51.4	12.5	66.6	50.9	10.5	66.3	51.5	8.5
↓	11	↓	↓	66.3	51.3	10.5	66.6	51.0	8.5	66.2	51.9	8.0
15	1	15		65.9	50.7	11.0	63.9	49.1	11.0	63.0	49.2	8.0
↓	↓	↓		*63.9	49.7	11.5	-	-	-	-	-	-
↓	11	↓		65.0	50.4	11.5	65.2	49.4	9.0	65.2	51.2	8.0
16	1	16		62.7	49.0	11.0	62.9	48.7	8.5	62.5	49.5	7.5
↓	↓	↓		-	-	-	*64.2	50.4	9.0	-	-	-
↓	11	↓		61.9	49.0	11.5	62.3	48.5	9.0	62.5	48.7	7.5
↓	↓	↓		*62.9	49.1	12.0	-	-	-	-	-	-
17	1	17		-	-	-	65.2	49.4	9.0	65.2	49.9	7.5
↓	11	↓		-	-	-	64.0	48.1	9.0	63.6	49.1	8.0
18	1	18		65.2	50.3	11.5	65.7	49.8	9.0	65.6	50.8	8.5
↓	11	↓		65.4	50.3	12.0	66.5	50.3	9.0	65.7	51.3	8.5
19	1	19		63.7	50.0	10.5	64.4	50.7	9.0	62.9	50.5	8.0
↓	11	↓		63.3	50.2	11.0	63.7	49.7	8.5	62.4	48.9	6.5
20	1	20		66.7	51.3	11.0	67.3	52.1	7.5	61.0	46.9	8.5
↓	↓	↓		*68.5	52.5	7.0	*67.5	52.2	10.5	-	-	-
↓	11	↓		66.8	52.0	10.0	63.8	49.4	9.5	62.7	48.9	8.5
↓	↓	↓	↓	*67.7	53.1	10.0	-	-	-	-	-	-
Min. Gtd. (Forger)				61	49	6	61	48	{4 seg. 5 {3 seg. 6-8	59	45	3

Forging and HT dimensions — ~5-3/4 - 14" t x ~29-1/2" w x ~115-1/2" l; Prolongatio
aged by forger.
1/2" D tensile specimens.

Note: All locations ℄ t and w.
* Retest specimens.

TABLE 9. 2219-T852 CONTOUR HAND FORGING
THRUST POST – DESTRUCT TEST

Forging P/N 14A20084(1)			Tensile Properties												Fracture Toughness		
			1/2" D Specimens												Compact Tension K_{1c} – ksi $\sqrt{in.}$		
S/N 1			Longitudinal				Long Transverse				Short Transverse						
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)	UTS ksi
2	t/2; edge†	~5 3/4	64.1	53.4	9.0	21.6	63.4	51.6	7.5	10.9	63.6	51.2	7.5	9.8	-	-	63.5
↓	w/2	↓	*64.4	50.9	10.0	22.9	*64.2	50.4	7.5	9.7	*63.7	50.9	5.0	4.7			63.9
↓	edge†	↓	64.9	52.9	12.0	27.2	64.0	52.4	7.5	9.4	64.5	51.8	(5)	6.7			63.8
																	63.7
10	edge†		63.6	52.9	11.0	24.7	63.4	50.6	6.5	6.7	63.8	51.4	5.0	5.0	-	-	65.4
↓	w/2	↓	*64.7	51.6	10.0	19.4	*64.4	50.2	5.0	10.1	65.0	51.3	5.5	8.5			64.6
↓	edge†	↓	67.4	54.7	11.0	22.2	64.3	51.6	5.0	7.3	67.7	55.6	5.5	7.4			65.1
																	65.0
																	(3)
																	63.9
																	62.5
																	61.7
																	62.7
5	t/4 bot.; edge†	~12	65.3	52.8	8.0	18.0	62.9	51.1	5.5	6.8	65.9	52.6	6.0	6.3	-	-	-
↓	w/2	↓	*61.5	47.2	8.0	16.8	*62.0	47.0	5.5	7.1	*59.4	46.3	4.5	7.0	(23.48) [0.590]	(4)	
↓		↓	-	-	-	-	-	-	-	-	-	-	-	-	(4)	(4)	
↓	edge†	↓	64.8	52.8	7.0	8.2	61.6	50.6	(5)	3.6	64.8	52.3	5.5	5.1	-	-	
6	w/4	~14	60.7	48.2	10.0	13.9	-	-	-	-	-	-	-	-	-	-	-
↓	w/3	↓	-	-	-	-	-	-	-	-	56.6	43.6	4.0	5.5	21.91		
↓	w/2	↓	60.3	47.6	10.5	21.9	-	-	-	-	-	-	-	-	-	-	
↓	w/3	↓	-	-	-	-	-	-	-	-	56.9	45.3	4.0	7.5	22.32		
↓	w/4	↓	60.7	48.4	10.5	16.5	-	-	-	-	-	-	-	-	-	-	
	t/4 top;	w/4	60.2	48.1	8.5	14.7	-	-	-	-	-	-	-	-	-	-	-
↓		w/3	59.3	47.5	10.0	23.9	-	-	-	-	-	-	-	-	-	(39.64) [1.033]	
↓		w/2	*60.4	48.1	10.0	22.2	-	-	-	-	-	-	-	-	-	-	
↓		w/3	59.8	47.4	11.0	23.6	-	-	-	-	-	-	-	-	-	(38.31) [1.058]	
↓		w/4	60.4	48.2	9.5	19.4	-	-	-	-	-	-	-	-	-	-	

See Page 55 for Notes

Stress Corrosion — 3 1/2% NaCl Alt. Imm.						
Short Transverse (℄ t and w; 1/4" D × 1" GL)						
Tensile Blanks			Unstressed		Stressed[2]	
TYS ksi	EL %	RA %	UTS	EL	UTS	EL
			% Change in 30 Days			
50.3	6.5	7.1	-24.0	-76.9	— FH —	
50.4	7.0	8.6	-26.5	-76.9	-25.4	-69.2
50.4	6.0	11.0	-22.3	-76.9	-27.2	-76.9
50.4	6.5	8.9	-24.5	-76.9	-26.4	-72.3
51.9	7.0	10.3	-22.3	-70.6	-28.3	-85.3
50.1	7.0	7.1	-22.9	-70.6	-27.7	-85.3
51.8	6.5	7.2	-24.2	-70.6	-25.1	-70.6
51.3	6.8	8.2	-23.0	-70.6	-27.1	-80.8
49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4
49.3	5.5	8.6	-26.0	-91.2	-26.3	-100
48.9	5.0	6.4	-27.3	-100	-29.2	-100
49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

TABLE 9. (Continued)

Forging P/N 14A20084(1)			Tensile Properties											
			1/2" D Specimens											
S/N 1			Longitudinal				Long Transverse				Short Transverse			
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %
6	t/2; w/2	~14	-	-	-	-	-	-	-	-	56.3	44.8	5.0	7.0
											56.1	44.5	5.5	7.5
8			-	-	-	-	-	-	-	-	56.6	43.9	7.0	8.6
											56.6	44.2	7.0	8.6
											-	-	-	-
2 & 10	Min. Gtd.	~5 3/4	61	49	6	-	61	48	4	-	59	45	3	-
5 & 9		~7 1/2-12	50	37	6	-	50	36	4	-	48	34	3	-
6 & 8		14	50	37	6	-	50	36	3	-	48	34	3	-

Notes:

(1) Forged and HT dimensions — ~5 3/4-14" t × ~29 1/2" w × ~115" l
Alcoa cut into segments before aged.

(2) Stressed to 75% TYS.

(3) Standard — specimens from 2219-T851 plate 6 1/8" t exposed simultaneously.

(4) Failed according to E399 sec. 8.2.4 — cracked at an angle >10°.

(5) Broke outside gauge marks.

FH — Failed in handling during removal from stressing fixture.

* — Stress-strain curves available.

† Surface for L and ST.

Legend:

( ) — K_Q values in parentheses

[ ] — R_{sc} values in brackets

1.5" wide specimens

racture Toughness		Stress Corrosion — 3.5% NaCl Alt. Imm.							
Compact Tension K_{1c} — ksi $\sqrt{in.}$		Short Transverse (G_L t and w; 1/4" D × 1" GL)							
		Tensile Blanks				Unstressed		Stressed(2)	
-L)	(L-S)	UTS ksi	TYS ksi	EL %	RA %	UTS	EL	UTS	EL
						% Change in 30 Days			
.84	-	-	-	-	-	-	-	-	-
.23	-								
.96	-	57.2	44.0	7.0	12.5	-21.5	-85.7	-24.4	-92.8
.46	-	57.2	43.9	7.0	10.8	-25.5	-92.8	-23.7	-92.8
.67	-	57.4	43.9	7.0	10.3	-20.9	-85.7	-24.6	-100
		57.3	43.9	7.0	11.2	-22.7	-88.6	-24.2	-95.7
		(3)							
		63.9	49.7	6.5	9.4	-25.5	-91.2	-26.3	-82.4
		62.5	49.3	5.5	8.6	-26.0	-91.2	-26.3	-100
		61.7	48.9	5.0	6.4	-27.3	-100	-29.2	-100
		62.7	49.3	5.7	8.1	-26.3	-94.7	-27.3	-94.7
		-	-	-	-	-	-	-	-

TABLE 9. (Continued)

Forging P/N 14A20084(1)			Tensile Properties												Fracture Toughness	
			1/2" D Specimens												Compact Tension K_{1c} – ksi $\sqrt{in.}$	
S/N 13			Longitudinal				Long Transverse				Short Transverse					
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)
2	t/2; edge†	~5 3/4	68.2	53.9	8.0	16.9	67.2	52.5	5.5	7.9	69.0	55.5	5.5	7.5	-	-
↓	w/2		66.7	51.2	9.5	23.3	67.4	50.9	7.0	11.6	67.8	53.4	5.0	7.5		
	edge†		68.7	55.4	8.5	16.9	67.3	52.7	4.5	7.5	68.7	56.1	5.0	4.8		
10	edge†		68.7	54.2	10.0	21.9	66.6	53.0	5.0	8.6	67.5	55.1	5.5	9.4	-	-
↓	w/2		66.0	50.7	9.5	20.4	67.0	50.5	7.0	12.7	67.0	52.2	6.0	8.3		
↓	edge†		70.2	55.1	9.5	20.1	67.1	52.8	5.5	7.9	68.4	55.9	6.0	7.9		
5	t/4 bot.; edge†	~12	68.7	56.3	7.5	15.4	64.0	52.7	5.0	5.1	68.9	56.6	7.0	5.1	-	(32.27) [0.722]
↓	w/2		not reported				64.0	48.7	6.0	7.1	63.7	49.1	6.0	8.6	25.44	(31.97) [0.863]
↓	edge†	↓	68.9	53.3	9.0	16.4	64.3	51.9	5.0	5.1	69.0	55.8	7.0	6.3	-	(35.41) [0.868]
6	w/4	~14	62.8	48.8	9.0	16.9	-	-	-	-	-	-	-	-	-	-
↓	w/3	↓	-	-	-	-	-	-	-	-	58.4	44.3	5.5	7.5	(27.41) [0.789]	-
↓	w/2	↓	60.9	46.9	9.5	18.8	-	-	-	-	-	-	-	-	-	-
↓	w/3	↓	-	-	-	-	-	-	-	-	58.7	44.8	5.5	6.7	(26.58) [0.755]	-
↓	w/4	↓	63.0	49.0	9.0	17.6	-	-	-	-	-	-	-	-	-	-
↓	t/4 top; w/4	↓	62.6	49.2	9.5	20.6	-	-	-	-	-	-	-	-	-	-
↓	w/3	↓	60.6	46.0	10.5	24.3	-	-	-	-	-	-	-	-	-	(41.34) [1.188]
↓	w/2	↓	59.1	46.6	10.0	21.9	-	-	-	-	-	-	-	-	-	-
↓	w/3	↓	60.3	45.9	9.5	22.7	-	-	-	-	-	-	-	-	-	(39.78) [1.072]
↓	w/4	↓	62.6	49.0	8.5	17.6	-	-	-	-	-	-	-	-	-	-
↓	t/2; w/2	↓	-	-	-	-	-	-	-	-	57.8	43.5	6.5	6.7	25.18	-
↓	↓	↓	-	-	-	-	-	-	-	-	57.8	44.0	7.0	10.5	26.37	-
8		↓	-	-	-	-	-	-	-	-	58.4	43.8	6.5	12.8	25.39	-
↓	↓	↓	-	-	-	-	-	-	-	-	58.3	44.1	6.5	8.6	26.25	-
															1 = not reported	

Notes:

(1) Forged and HT dimensions — ~5 3/4-14" t × ~29 1/2" w × ~115 1/2" l.
Forger cut into segments before aged.

†Surface for L and ST.

Legend:

( ) — K_Q values in parentheses

[ ] — R_{sc} values in brackets

1.5" wide specimens

TABLE 9. (Concluded)

Forging P/N 14A20084[1]			Tensile Properties												Fracture Toughness	
			1/2" D Specimens												Compact Tension K_{1c} -- ksi $\sqrt{in.}$	
S/N 19			Longitudinal				Long Transverse				Short Transverse					
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(L-S)
2	t/2; edge†	~5 3/4	63.4	51.9	10.0	24.3	61.9	49.6	6.0	9.8	62.5	52.8	7.0	10.5	-	-
↓	w/2	↓	62.0	49.1	9.5	25.1	61.9	47.6	7.5	12.0	62.3	50.0	6.5	10.5		
	edge†		64.2	51.9	10.0	23.4	62.6	50.4	7.0	11.6	63.7	52.8	6.0	8.5		
10	edge†		61.5	51.8	9.0	23.3	60.3	48.5	5.0	8.6	60.8	50.6	6.0	7.5	-	-
↓	w/2		61.5	48.3	10.0	25.8	61.4	48.4	6.0	8.6	61.5	48.9	6.0	8.2		
	edge†		62.1	52.7	10.0	29.5	61.7	48.6	5.5	8.2	62.6	51.5	7.0	9.0		
5	t/4 bot.; edge†	~12	63.4	50.9	8.0	17.6	59.7	47.9	4.0	7.4	63.1	51.0	5.0	9.4	(21.17)[0.574]	(2)
↓	w/2	↓	57.6	44.9	8.5	16.4	58.1	45.0	7.0	10.1	58.0	45.4	5.0	10.9	(21.17)[0.585]	(2)
	edge†		62.2	49.5	9.5	16.8	59.7	47.6	5.0	8.9	62.3	50.0	6.0	8.9	-	-
6	w/4	~14	57.5	45.9	10.0	23.4	-	-	-	-	-	-	-	-		
↓	w/3	↓	-	-	-	-	-	-	-	-	55.2	42.6	5.5	9.4	(20.22)[0.610]	
	w/2		56.0	43.4	10.5	22.4	-	-	-	-	-	-	-	-		
	w/3		-	-	-	-	-	-	-	-	55.3	43.1	6.0	8.9	(20.21)[0.597]	
	w/4		57.5	45.9	10.5	23.5	-	-	-	-	-	-	-	-		
	t/4 top; w/4		57.5	46.1	10.0	23.0	-	-	-	-	-	-	-	-	-	-
	w/3		55.6	43.2	10.5	22.9	-	-	-	-	-	-	-	-	-	26.22
	w/2		56.1	43.4	10.0	20.2	-	-	-	-	-	-	-	-	-	-
	w/3		56.2	43.6	10.0	21.1	-	-	-	-	-	-	-	-	-	25.93
	w/4		57.8	46.2	10.0	20.5	-	-	-	-	-	-	-	-	-	-
↓	t/2; w/2		-	-	-	-	-	-	-	-	54.8	42.3	6.5	10.9	(20.38)[0.616]	-
											55.0	42.4	4.5	7.8	20.72	-
8			-	-	-	-	-	-	-	-	55.2	43.0	6.5	9.3	(20.10)[0.593]	-
↓											55.4	43.0	5.0	6.2	(20.45)[0.631]	-
											-	-	-	-	(19.77)[0.600]	-

Notes:

(1) Forged and HT dimensions — ~5 3/4-14" t × ~29 1/2" w × ~115 1/2" l. Forger cut into segments before aged.

(2) Failed acc. to E399 sec. 8.2.4 — cracked at angle >10° — actual ~44-50°.

†Surface for L and ST.

Legend:

( ) — K_Q values in parentheses

[ ] — R_{sc} values in brackets

1.5" wide specimens

TABLE 10. 2219-T852 CONTOUR HAND FORGING — DETAILED SUMMARY COMBINED TESTS — THRUST POST — 14A20084

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal El e/4D %	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse El e/4D %	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse El e/4D %	Short Transverse RA %
Forger Min. Gtd.		5 3/4	61	49	6	-	61	48	4	-	59	45	3	-
(15)			62.2-69.0	49.7-52.6	7.5-13.0	-	(15) 61.5-67.5	48.1-51.7	5.5-11.0	-	(15) 61.5-68.5	48.9-54.7	4.5-8.5	-
3 destruct A	Q & E	~5 3/4												
(18)			61.5-70.2	48.3-55.1	7.0-12.0	16.9-29.1	(18) 60.1-67.1	47.0-53.0	4.5-7.5	6.7-12.7	(24) 60.8-69.0	48.9-56.1	5.0-7.5	4.7-11.0
M														
(3)			59.4-59.7	45.0-45.1	8.0-8.5	21.2-23.0	-	-	-	-	-	-	-	-
*1 x-skirt M	Q													
(25)			61.9-68.5	49.0-56.3	7.0-12.5	-	(39) 62.4-67.8	48.0-52.7	7.0-11.0	-	(34) 61.0-67.5	46.9-53.3	6.5-9.5	-
17 Prol. A														
*1 x- M			-	-	-	-	(6) 64.0-65.3	49.1-51.8	6.0-7.5	8.2-13.2	(6) 63.6-65.8	50.8-51.6	4.0-5.5	4.0-8.2
Forger Min. Gtd.		7 1/2-12	50	37	6	-	50	36	4	-	48	34	3	-
(9)			60.1-66.0	46.5-50.6	10.5-11.5	-	(9) 59.8-65.6	45.5-50.8	5.0-9.0	-	(9) 57.8-66.2	44.6-51.0	6.0-9.0	-
3 destruct A	Q & 1/4 w	~7 1/2												
(8)			57.6-68.9	43.9-56.3	7.0-9.5	8.2-18.0	(9) 58.1-61.3	45.0-52.7	4.0-7.0	3.6-10.1	(9) 58.0-69.0	46.3-56.6	4.5-7.0	5.1-10.9
3 destruct M	1/4 t	~12												
*1 x-skirt M	Q		-	-	-	-	-	-	-	-	(3) 53.9-54.7	41.7-43.0	7.5-8.0	10.2-12.7
Forger Min. Gtd.		14	50	37	6	-	50	36	3	-	48	34	3	-
(18)			57.1-66.7	44.5-51.4	9.0-11.5	-	(46) 50.0-56.0	42.1-54.7	(1) 2.5-8.5	-	(36) 54.1-64.2	44.5-51.0	4.5-8.0	-
3 destruct A	Q & 1/4 w	~14												
(24)			59.1-63.0	43.7-49.2	8.5-11.0	14.9-24.1	-	-	-	-	(6) 55.2-58.2	43.6-45.4	6.5-8.0	8.5-9.4
M	1/4 t													
M	Q		-	-	-	-	-	-	-	-	(12) 54.8-58.4	43.2-44.7	6.0-7.0	9.2-12.8
(3)														
*1 x-skirt M			53.3-56.1	42.9-43.6	10.5-11.0	27.4-28.1	-	-	-	-				

A Mech test
M MDAC test
* MDAC hood, all others were forger's cut
x stimulation age
skirt MDAC 1/4 t cut, destructed
Prol. position directly adjacent to
○ No. of [illegible] and [illegible] test [illegible] values [illegible]

[illegible] duplicate and [illegible]

TABLE 11. 2219-T852 CONTOUR HAND FORGING — CONDENSED SUMMARY
COMBINED TESTS — THRUST POST — 14A20084

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL %/4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL %/4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL %/4 D	Short Transverse RA %
Forger Min. Gtd.		5 3/4	61	49	6	-	61	48	4	-	59	45	3	-
20(1)	$\mathbb{C}_L$; E	~5 3/4	(18) 61.5-70.2	48.3-56.3	7.0-13.0	(18) 16.9-29.5	(18) 60.3-67.8	47.6-53.0	4.5-11.0	(18) 6.7-13.2	(24) 60.8-69.0	46.9-56.1	4.0-9.5	(24) 4.0-11.0
1(2)	$\mathbb{C}_L$	↓	(3) 59.4-59.7	45.0-45.4	8.0-8.5	(3) 21.2-23.0	-	-	-	-	-	-	-	-
Forger Min. Gtd.		7 1/2-12	50	37	6	-	50	36	4	-	48	34	3	-
3(3)	$\mathbb{C}_L$; 1/4 w	~7 1/2	(9) 60.1-66.0	46.5-50.6	10.5-11.5	-	(9) 59.8-66.6	45.5-50.8	5.0-9.0	-	(9) 57.8-66.2	44.6-51.0	6.0-9.0	-
3(3)	1/4 t	~12	(9) 57.6-68.9	44.9-56.3	7.0-9.5	(9) 8.2-18.0	(8) 58.1-64.3	45.0-52.7	4.0-7.0	(8) 3.6-10.1	(9) 58.0-69.0	46.3-56.6	4.5-7.0	(9) 5.1-10.9
1(2)	↓	↓	-	-	-	-	-	-	-	-	(3) 53.9-54.7	41.7-43.0	7.5-8.0	(3) 10.2-12.7
Forger Min. Gtd.		14	50	37	6	-	50	36	3	-	48	34	3	-
3(3)	Varied	~14	(42) 55.6-66.7	43.2-51.8	8.5-11.5	(24) 13.9-24.3	(46) 50.0-70.6	42.4-54.7	(4) 2.5-8.5	-	(34) 54.1-64.3	42.3-51.0	4.0-8.0	(18) 5.5-12.8
1(2)	$\mathbb{C}_L$	↓	(3) 55.3-56.3	42.9-43.6	10.5-11.0	(3) 27.5-28.5	-	-	-	-	-	-	-	-

(1) 3 destruct +17 prolongation tests each end
(2) 1 destruct from MDAC aged 1/4 skirt
(3) 3 destruct
(4) 2.5% for one specimen at 1/4 w, duplicate and original were 3%
◯ = No. of 1/2" and 1/4" D specimens tested; min. to max. values obtained

Forged and HT dimensions ~5 3/4-14" t × ~29 1/2" w × ~115 1/2" l

TABLE 12. FORGER DATA — 2219-T852 RECTANGULAR HAND FORGING SPLICE FITTING — PROLONGATION TESTS AND DESTRUCT TEST

Prolongation Tests Forging P/N 14A30500				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	001	2365	~8	-	-	-	59.4	45.2	7.1	59.3	43.4	7.1
C	↓	↓	↓	↓	↓	↓	59.9	46.1	7.9	60.5	45.5	5.7
A	003	2275	↓	↓	↓	↓	59.9	46.8	7.9	59.7	44.2	7.1
B	↓	↓	↓	↓	↓	↓	62.0	48.5	7.1	61.2	45.4	7.9
	004	2372	↓	↓	↓	↓	59.2	45.6	7.9	59.3	45.3	6.4
	↓	↓	↓	↓	↓	↓	60.1	46.9	7.1	61.1	47.2	6.4
	005	2230	↓	↓	↓	↓	61.8	47.1	7.9	61.7	47.0	5.7
	↓	↓	↓	↓	↓	↓	65.2	51.1	7.1	65.0	50.5	6.4
	006	↓	↓	↓	↓	↓	64.3	50.2	6.4	63.8	48.3	5.0
	↓	↓	↓	↓	↓	↓	61.2	46.5	7.1	61.1	46.2	6.4
	007	2377	↓	↓	↓	↓	60.6	47.4	7.9	60.6	46.1	6.4
	↓	↓	↓	↓	↓	↓	59.4	45.5	7.9	59.3	44.2	7.1
	008	2254	↓	↓	↓	↓	58.2	45.6	7.1	58.9	43.9	6.4
	↓	↓	↓	↓	↓	↓	59.4	46.0	7.9	59.6	44.2	5.7
	009	2239	↓	↓	↓	↓	62.5	47.6	7.1	62.9	47.5	6.4
	↓	↓	↓	↓	↓	↓	65.6	50.4	7.1	64.9	49.0	6.4
	010	2259	↓	↓	↓	↓	60.9	46.7	6.4	61.1	46.6	6.4
	↓	↓	↓	↓	↓	↓	62.1	47.4	6.4	61.9	46.8	5.7
	011	2239	↓	↓	↓	↓	61.8	48.1	6.4	61.8	46.2	6.4
	↓	↓	↓	↓	↓	↓	67.6	53.0	7.1	66.6	50.8	5.7
	012	2257	↓	↓	↓	↓	63.0	47.7	7.1	63.3	47.7	6.4
	↓	↓	↓	↓	↓	↓	61.8	47.0	7.9	62.1	45.7	6.4
	013	2254	↓	↓	↓	↓	60.4	46.8	7.1	61.0	45.4	7.1
	↓	↓	↓	↓	↓	↓	59.6	45.6	7.1	60.0	44.2	7.1
	014	2259	↓	↓	↓	↓	59.3	45.6	7.1	59.6	44.1	7.9
	↓	↓	↓	↓	↓	↓	60.0	45.9	9.3	60.2	44.5	8.6
	015	2257	↓	↓	↓	↓	68.1	53.1	6.4	67.5	50.8	6.4
	↓	↓	↓	↓	↓	↓	63.7	49.5	7.9	63.5	47.6	7.1

TABLE 12. (Continued)

Prolongation Tests Forging P/N 14A30500				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	016	2361	~8	-	-	-	60.6	48.2	6.4	60.6	47.8	6.4
B							60.9	48.3	7.1	61.0	47.5	7.1
	017	2257					63.5	47.6	9.3	62.1	46.2	7.1
							64.2	48.9	8.6	64.9	48.2	7.1
	018	2259					59.9	46.0	7.9	59.6	44.3	7.9
							61.0	46.9	7.1	61.0	45.8	7.1
	019	2254					60.8	46.6	9.3	60.4	45.4	7.9
							61.9	47.8	7.9	61.9	47.0	8.6
	020	2301					60.5	46.5	7.9	60.7	45.1	7.9
							61.2	46.5	7.9	61.5	46.8	6.4
	021	2377					58.4	44.8	7.9	59.4	43.9	6.4
							60.1	46.5	7.1	60.2	45.8	6.4
	022	2275					60.6	46.6	8.6	60.6	46.4	7.1
							57.8	43.5	8.6	58.2	43.7	6.4
	023	2389					60.4	47.2	7.9	60.3	46.1	6.4
							61.2	48.1	6.4	61.2	46.6	6.4
	024	2365					60.2	46.4	7.9	60.4	45.5	7.9
							59.3	45.2	8.6	60.4	43.4	7.9
	025	2367					59.8	44.5	7.9	59.5	43.7	7.1
							59.9	46.1	7.1	59.9	44.8	7.9
	026	2361					61.1	48.6	6.4	61.6	47.9	6.4
							62.3	49.5	6.4	62.3	48.9	5.0
	027	2372					58.6	45.6	7.9	58.6	44.4	7.1
							59.9	45.9	8.6	60.6	46.0	7.1
	028	2367					60.0	46.0	7.9	60.9	45.8	7.1
							59.6	45.5	7.1	60.3	44.7	7.1
	029	2230					63.3	51.2	6.4	63.3	49.9	3.6
							66.8	53.8	6.4	67.1	52.7	6.4
	030	2361					60.9	47.1	7.1	61.1	44.9	7.1
							59.8	45.5	7.9	60.0	45.2	7.9

TABLE 12. (Continued)

Prolongation Tests Forging P/N 14A30500				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	031	2372	~8	-	-	-	62.7	49.4	6.4	63.3	49.0	5.7
B							62.1	49.5	6.4	62.1	48.6	6.4
	032	2301					58.9	44.7	8.6	59.0	43.5	7.1
							60.2	45.5	7.9	59.7	44.0	8.6
	033	2275					59.8	45.1	7.1	59.0	42.9	7.1
							60.4	45.9	7.1	60.7	44.6	7.1
	034	2365					58.7	45.0	8.6	59.3	44.3	7.9
							57.6	44.2	7.9	58.4	43.9	8.6
	035	2384					62.5	50.0	5.7	62.2	46.1	6.4
							63.3	49.5	5.7	62.5	48.4	5.7
	036	2301					59.2	45.2	9.3	59.2	42.7	7.1
							59.1	45.3	7.1	58.5	43.3	5.7
	037	2391					60.9	47.8	7.1	60.7	46.2	8.6
							59.1	45.7	9.3	59.1	44.4	7.9
	038	2239					59.5	44.7	10.0	60.0	45.4	8.6
							63.9	48.5	6.4	63.9	48.2	5.7
	039	2367					58.2	44.0	7.1	58.5	43.1	6.4
							59.6	45.8	7.9	59.5	44.2	7.1
	040	2384					59.3	45.7	6.4	59.8	46.1	7.1
							60.3	46.6	5.7	60.3	45.9	9.3
	041	2374					59.9	45.9	8.6	60.1	44.5	7.9
							57.3	45.3	7.9	58.7	44.0	7.1
	042						59.4	45.8	7.9	59.7	44.5	7.9
							60.1	46.5	8.6	60.9	45.1	6.4
	043	2379					59.8	46.0	7.9	59.4	44.2	7.9
							58.5	43.9	8.6	58.5	42.9	7.9
	044						59.0	45.2	8.6	59.3	44.7	6.4
							59.1	43.7	8.6	59.1	45.1	6.4
	045	2381					59.9	45.3	8.6	60.5	45.0	6.4
							59.6	44.1	7.1	59.6	43.9	7.1

TABLE 12. (Continued)

Prolongation Tests Forging P/N 14A30500				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	046	2381	~8	-	-	-	60.9	47.0	9.3	60.8	45.4	7.1
B							59.6	45.7	8.6	59.3	44.3	9.3
	047	2384					59.4	45.2	8.6	58.9	43.7	7.9
							60.7	47.2	9.3	60.2	45.4	7.9
	048	2389					59.1	45.9	8.6	59.4	44.0	7.9
							58.2	45.4	7.9	58.9	44.0	7.9
	049	2373					60.2	46.8	7.1	60.3	45.1	7.1
							58.6	43.8	7.9	58.8	43.2	7.1
	050	2374					57.9	45.0	7.1	59.6	45.0	7.9
							57.9	44.9	7.1	58.1	43.3	7.9
	051	2391					60.0	44.8	7.1	60.5	45.7	6.4
							61.8	48.8	9.3	61.3	45.9	7.9
	052	2377					61.6	48.9	5.7	60.8	46.0	6.4
							60.4	48.6	7.1	60.4	46.6	7.9
	053	2373					59.4	46.2	7.1	59.6	44.8	7.9
							58.5	46.1	7.1	58.9	44.3	7.9
	054						58.5	45.3	7.9	58.9	44.0	8.6
							58.3	44.1	7.9	59.1	44.2	8.4
	055	2389					57.3	43.5	10.0	58.0	43.4	7.1
							58.1	44.9	9.3	58.3	43.4	9.3
	056	2379					63.1	49.1	6.4	63.5	47.6	6.4
							58.4	43.9	10.0	58.8	43.2	7.9
	057	2385					58.6	44.4	8.6	58.0	42.5	8.6
							57.5	43.7	9.3	57.3	42.7	8.6
	058	2391					59.0	46.1	10.0	58.6	43.9	9.3
							59.6	46.8	7.1	59.3	45.2	7.9
	059	2385					57.1	43.1	9.3	57.3	41.2	7.9
							59.3	46.2	10.0	59.1	44.4	8.6
	060						58.3	43.9	9.3	58.8	42.9	7.1
							57.8	44.0	9.3	58.1	42.5	8.6

TABLE 12. (Concluded)

Prolongation Tests				Tensile Properties								
Forging P/N 14A30500				Longitudinal			Long Transverse			Short Transverse		
Seg.	S/N	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	061	2397	~8	-	-	-	59.0	46.3	8.6	59.2	44.2	8.6
B							59.1	46.6	7.1	58.9	45.7	7.1
	062	2444					58.6	44.3	8.6	59.4	42.5	8.6
							57.8	43.3	7.9	57.9	42.0	7.1
Destruct Test				Destruct Forging								
A	001	2365	~8	-	-	-	59.4	45.2	7.1	59.3	43.4	7.1
1				59.6	45.4	10.0	59.6	44.9	7.1	59.4	44.8	7.9
4				59.7	46.7	10.7	59.1	45.0	8.6	58.8	44.7	7.9
9				60.3	46.8	10.0	59.6	46.0	8.6	59.3	45.2	7.1
C				-	-	-	59.9	46.1	7.9	60.5	45.5	5.7
Forger Min. Gtd.			8	57	44	6	57	43	4	55	40	3

Forging and HT dimensions — ~8" t x ~11" w x ~110" l
0.357" D x 1.40" gage length tensile specimens ~℄ t and w
A and B are prolongations from opposite ends of the 100" long deliverable forging
A and C are prolongations from opposite ends of the destruct forging
Prolongations and destruct forging aged by forger, remainder delivered -T352 temper

Chemical Analysis of Mill Melt											
No. of S/N	Cu	Zr	V	Mg	Ti	Si	Fe	Zn	Mn	Cr	Mill Melt No.
25	5.82	.13	.10	.004	.05	.08	.24	.03	.26	.001	AH766-06-1, -2, -3, -4
14	5.94	.14	.10	.004	.06	.09	.26	.02	.29	.001	AH766-10-2, -3, -7
1	6.04	.15	.06	.011	.06	.093	.20	.008	.26	.001	AH701-06-2
2	6.16	.15	.07	.008	.054	.10	.22	.009	.27	.001	AH701-07-4
13	6.17	.14	.10	.004	.06	.09	.27	.02	.26	.000	AH766-06-1, -4
2	6.24	.15	.11	.009	.056	.088	.21	.015	.27	.001	AH989-23-4
4	6.35	.13	.05	.023	.058	.10	.22	.010	.26	.002	AH701-05-4

Data represent: 7 mill melt cast nos. for 13 ingot drops 14-1/2" t x 44" w rectangular
61 forged lengths, Mil-I-8950B, Class B, AM #1
22 heat treat lots

TABLE 13. MDAC TEST DATA — 2219-T852 RECTANGULAR HAND FORGING
SPLICE FITTING — DESTRUCT TEST

Forging P/N 14A30500(1)			Tensile Properties												Fracture Toughne	
			1/2" D Specimens												Compact Tensio K_{1c} — ksi $\sqrt{\text{in.}}$	
S/N 001			Longitudinal				Long Transverse				Short Transverse					
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(T-S
2	~1/4 t; ~℄ w	8	-	-	-	-	*62.0	47.2	7.5	13.8	*59.0	44.1	8.0	16.0	30.56	31.7
↓	↓	↓	-	-	-	-	-	-	-	-	59.4	44.3	7.5	12.3	30.73	-
5			-	-	-	-	*62.1	47.2	8.0	10.8	*58.3	44.2	8.5	15.6	33.20	(35.70)[1
↓			-	-	-	-	-	-	-	-	58.5	44.2	10.0	21.5	32.71	-
8			-	-	-	-	*62.2	47.0	8.0	15.3	*60.0	45.3	7.5	12.3	28.90	34.0
↓			-	-	-	-	-	-	-	-	60.1	45.6	7.0	9.3	28.07	-
3	℄ t; edge		*62.6	49.4	9.0	26.4	-	-	-	-	-	-	-	-		-
↓	↓	↓	64.9	48.9	11.0	26.4	-	-	-	-	-	-	-	-		
			*65.1	50.9	11.0	24.6	-	-	-	-	-	-	-	-		
	1/4 w		-	-	-	-	59.7	-	7.0	12.8	-	-	-	-		
	↓		-	-	-	-	59.7	46.2	7.0	9.0	-	-	-	-		
			-	-	-	-	59.6	45.7	7.5	14.2	-	-	-	-		
			-	-	-	-	59.5	45.3	8.0	15.0	-	-	-	-		
↓	& w		59.4	45.9	12.0	33.1	-	-	-	-	-	-	-	-		
7	edge		*63.3	49.3	11.5	28.4	-	-	-	-	-	-	-	-	-	-
↓	↓		63.0	49.1	11.0	26.1	-	-	-	-	-	-	-	-		
			65.7	51.0	11.0	25.7	-	-	-	-	-	-	-	-		
	1/4 w		-	-	-	-	58.2	45.1	8.0	13.1	-	-	-	-		
	↓		-	-	-	-	59.1	45.4	8.0	14.6	-	-	-	-		
			-	-	-	-	60.6	46.5	7.5	13.4	-	-	-	-		
			-	-	-	-	60.5	46.4	7.5	12.0	-	-	-	-		
↓	& w		59.3	45.3	13.0	34.4	-	-	-	-	-	-	-	-		
Min. Gtd.		↓	57	44	6	-	57	43	4	-	55	40	3	-		

Notes:
(1) Forged and HT dimensions — ~8" t × ~11" w × ~110" l.
(2) Stressed to 75% TYS.
(3) Standard = Specimens from 2219-T851 plate 6 1/8" t exposed simultaneously.
* — Stress-strain curves available.

Legend:
( ) — K_Q values in parentheses
[ ] — R_{sc} values in brackets
1.5" wide specimens

ess		Stress Corrosion — 3 1/2% NaCl Alt. Imm.							
n		Short Transverse (L t and w; 1/4" D × 1" GL)							
		Tensile Blanks				Unstressed		Stressed(2)	
)	(L-S)	UTS ksi	TYS ksi	EL %	RA %	UTS	EL	UTS	EL
						% Change in 30 Days			
0	-	-	-	-	-	-	-	-	-
.272]	-	58.3	44.6	9.5	14.7	-19.3	-73.7	-21.8	-63.2
	-	58.1	44.4	9.5	16.2	-16.7	-73.7	-28.9	-84.2
		57.8	43.4	9.5	12.3	-18.2	-73.7	-18.8	-73.7
		58.1	44.1	9.5	14.4	-18.1	-73.7	-23.2	-73.7
8	-	-	-	-	-	-	-	-	-
	-								
	-	(3)							
		63.9	49.7	6.5	9.4	-24.7	-90.9	-31.7	-100
		62.5	49.3	5.5	8.6	-24.6	-72.7	-	-
		61.7	48.9	5.0	6.4	-22.8	-90.9	-25.4	-72.7
		62.7	49.3	5.7	8.1	-24.0	-84.8	-28.5	-86.8
	-	-	-	-	-	-	-	-	-

TABLE 13. (Concluded)

Forging P/N 14A30500(1)			Tensile Properties										Fracture Toughness		
			1/2" D Elevated Temperature Specimens — Longitudinal										Compact Tension K_{1c} — ksi $\sqrt{in.}$		
S/N 001			RT				200°F				300°F				
Seg. No.	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	RT (L-S)	200°F (L-S)	300°F (L-S)
3	℄	8	59.4	45.9	12.0	33.1	52.4	43.3	17.0	41.6	-	-	-	-	-	-	-
↓	↓	↓	59.4	45.5	11.0	25.8	-	-	-	-	-	-	-	-	(43.69)[1.569]	-	-
			59.2	45.7	10.0	23.3	-	-	-	-	-	-	-	-	(43.27)[1.481]	(36.58)[1.601]	(31.25)[1.260]
			59.6	45.8	11.0	26.4	-	-	-	-	-	-	-	-	(43.51)[1.404]	(36.79)[1.516]	(31.74)[1.202]
			60.0	45.9	12.0	27.7	*52.2	43.0	17.0	42.0	*44.7	40.4	20.0	58.1	-	(36.83)[1.199]	(34.58)[1.255]
	edge		65.1	50.9	11.0	24.6	-	-	-	-	49.3	43.7	18.0	45.7	-	-	-
7	℄		59.3	45.3	13.0	34.4	53.5	44.0	17.5	47.0	-	-	-	-	-	-	-
↓	↓		59.1	44.8	12.5	33.1	-	-	-	-	-	-	-	-	(39.73)[1.263]	-	-
			60.4	46.1	11.0	22.6	-	-	-	-	-	-	-	-	(40.98)[1.353]	-	(34.85)[1.508]
			60.2	46.3	11.0	26.1	-	-	-	-	-	-	-	-	(40.69)[1.233]	(36.84)[1.213]	(36.03)[1.462]
			60.6	46.5	10.5	24.6	52.8	43.6	17.0	40.0	45.1	40.5	20.5	55.1	-	(36.05)[1.462]	(34.52)[1.554]
	edge	↓	65.7	51.0	11.0	25.7	-	-	-	-	48.4	43.5	17.5	49.3	-	-	-

Notes:
(1) Forged and HT dimensions — ~8" t × ~11" w × ~110" l
* — Stress-strain curves available.

Legend:
( ) — K_Q values in parentheses
[ ] — R_{sc} values in brackets
1.5" wide specimens

TABLE 14. 2219-T852 RECTANGULAR HAND FORGING — SUMMARY
COMBINED TESTS — SPLICE FITTING — 14A30500

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL %/4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL %/4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL %/4 D	Short Transverse RA %
Forger Min. Gtd.		8	57	44	6	-	57	43	4	-	55	40	3	-
1 destruct W	℄	~8	(3) 59.6-60.3	45.4-46.8	10.0-10.7	-	(5) 59.1-59.9	44.9-46.1	7.1-8.6	-	(5) 58.8-60.5	43.1-45.5	5.7-7.9	-
↓ ↓ M	℄; E	↓	(16) 59.1-65.7	44.8-51.0	9.0-13.0	22.6-34.4	(11) 58.2-62.2	45.1-47.2	7.0-8.0	9.0-15.3	(9) 57.8-60.1	43.4-45.6	7.0-10.0	9.3-21.5
60 Prol. W	℄	↓	-	-	-	-	(120) 57.1-68.1	43.1-53.8	5.7-10.0	-	(120) 57.3-67.5	41.2-52.7	3.6-9.3	-
61 total	℄; E	~8	(19) 59.1-65.7	44.8-51.0	9.0-13.0	(16) 22.6-34.4	(136) 57.1-68.1	43.1-53.8	5.7-10.0	(11) 9.0-15.3	(134) 57.3-67.5	41.2-52.7	3.6-10.0	(9) 9.3-21.5

W = Weber test, 0.357" D × 1.40" gage length tensile specimens
M = MDAC test, 1/2" D tensile spec. for properties, 1/4" D ST for stress corrosion
◯ = No. of specimens tested; min. to max. values obtained

Forged and HT dimensions ~8 1/2" t × ~11" w × ~110" l

TABLE 15. FORGER DATA — 2219-T852 RECTANGULAR HAND FORGINGS — ACTUATOR BRACKET — DESTRUCT TEST

Forging P/N 14A30905				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
A	1	2182	10-1/2	60.8	47.4	10.0	58.5	46.1	7.1	58.4	43.8	9.3
↓	5	↓	↓	60.7	45.6	10.7	58.7	45.4	7.1	58.4	42.5	7.1
↓	7	↓	↓	61.6	47.1	10.0	58.7	45.9	5.0	58.7	43.2	7.9
↓	10	↓	↓	62.5	45.8	9.3	59.8	42.7	7.9	59.8	42.7	7.9
B	1			60.9	47.0	10.7	58.8	45.9	9.3	57.9	43.3	9.3
↓	5	↓	↓	60.0	45.2	10.7	56.9	44.4	7.9	56.3	42.0	9.3
↓	7	↓	↓	59.9	45.8	10.0	57.9	45.1	8.6	57.5	42.7	8.6
↓	10	↓	↓	60.5	45.7	10.0	58.6	45.2	7.9	57.5	42.0	7.1
C	1	2187		61.8	45.4	10.7	59.0	43.2	7.1	59.5	44.9	9.3
↓	5	↓	↓	61.5	46.5	11.4	62.4	48.7	10.0	63.7	47.9	8.6
↓	7	↓	↓	63.7	48.0	9.3	60.6	46.5	7.1	59.9	44.9	7.1
↓	10	↓	↓	63.8	48.8	10.0	61.4	48.0	7.9	60.8	45.6	6.4
D	1	2181		61.9	47.8	10.0	60.0	47.7	7.1	59.4	44.4	7.1
↓	5	↓	↓	62.4	48.3	10.0	59.7	47.5	8.6	59.5	44.1	8.6
↓	7	↓	↓	63.0	47.5	10.0	60.4	47.0	8.6	59.6	43.9	8.6
↓	10	↓	↓	63.5	49.6	9.3	60.7	48.8	7.1	59.9	43.7	8.6
E	1	2189		62.1	48.8	10.7	60.2	46.6	7.9	59.3	43.5	9.3
↓	5	↓	↓	59.9	47.1	10.7	58.7	45.8	6.4	57.5	43.7	5.7
↓	7	↓	↓	63.0	48.5	10.7	60.6	47.0	8.6	60.3	44.2	9.3
↓	10	↓	↓	62.7	48.6	10.7	60.6	46.1	10.0	60.0	44.5	9.3
F	1	2187		62.1	48.9	10.0	59.1	44.9	8.6	58.9	46.7	6.4
↓	5	↓	↓	62.6	49.5	10.7	59.8	47.4	8.6	59.9	44.9	9.3
↓	7	↓	↓	61.6	48.1	10.0	62.9	50.2	7.9	63.8	48.4	7.9
↓	10	↓	↓	61.1	48.1	10.0	59.6	46.4	9.3	58.0	44.3	7.9

TABLE 15. (Concluded)

Forging P/N 14A30905				Tensile Properties								
				Longitudinal			Long Transverse			Short Transverse		
S/N	Seg.	Heat Lot	t in.	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
G	1	2181	~10-1/2	60.9	46.9	10.0	61.9	47.9	5.0	58.7	43.5	7.9
↓	5	↓	↓	60.8	47.4	10.0	57.5	48.8	5.7	58.4	43.4	6.4
↓	7	↓	↓	61.5	48.8	10.0	60.4	49.0	7.9	58.5	44.7	7.9
↓	10	↓	↓	60.6	47.0	11.4	63.2	49.8	5.0	58.7	44.7	6.1
H	3	2444	↓	56.5	43.5	10.3	55.7	44.0	6.4	57.1	43.7	7.9
Forger Min. Gtd.			10-1/2	52	39	6	52	38	4	50	36	3

Forged dimensions — ~10-1/2" t x ~10-1/2" w x ~180" l
HT dimensions — ~10-1/2" t x ~10-1/2" w x ~33" l
0.357" D x 1.40" gage length tensile specimens ℄ t and w

Chemical Analysis of Mill Melt											
S/N	Cu	Zr	V	Mg	Ti	Si	Fe	Zn	Mn	Cr	Mill Melt No.
A, B, E	6.04	.15	.06	.011	.06	.093	.20	.008	.26	.001	AH701-06-2, -3
C, D, F, G	6.35	.13	.05	.023	.058	.10	.22	.010	.26	.002	AH701-05-2
H	6.24	.15	.11	.009	.056	.088	.21	.015	.27	.001	AH989-23-2

Data represent: 3 mill melt cast nos. for 4 ingot drops 14-1/2" t x 44-1/2" or 50" w rectangular
7 forger mults + 1 single forged piece, Mil-I-8950B, Class B, AM#1
5 heat treat lots, total 36 pieces
All material aged by forger, delivered -T852 temper

TABLE 16. MDAC TEST DATA — 2219-T852 RECTANGULAR HAND FORGING
ACTUATOR SUPPORT BRACKET

Forging P/N 14A30905(1)			Tensile Properties										Fracture Toughness			Stress	
			1/2" D Specimens										Compact Tension K_{1c} — ksi $\sqrt{in.}$			Short T	
Seg. No. 4			Longitudinal				Long Transverse				Short Transverse					Tensile B	
Forging S/N	Location	t in.	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	UTS ksi	TYS ksi	EL %	RA %	(S-L)	(T-S)	(L-S)	UTS ksi	TYS ksi
B	℄ t & w	10 1/2	*59.1	44.3	12.5	27.7	*60.0	46.9	7.5	11.3	*59.1	43.8	6.0	8.6	25.89	26.04	(35.092)[1.149]	56.7	41.9
			58.7	44.5	11.0	27.3	56.0	44.5	5.0	7.8	61.1	46.7	7.5	12.4	-	-	-	56.9	42.7
			58.9	44.4	11.8	27.5	58.0	45.7	5.8	9.6	60.1	45.2	6.8	10.5				56.8	42.5
																		56.8	42.4
																		(3)	
																		63.9	49.7
																		62.5	49.3
C			63.2	47.6	10.0	24.6	60.3	46.9	8.5	13.5	65.5	49.8	6.5	5.1	31.64	29.10	(37.118)[1.126]	61.7	48.9
			63.2	47.9	10.0	17.0	63.3	49.2	7.5	13.9	64.4	48.4	8.0	12.4	-	-	-	62.7	49.3
			63.2	47.8	10.0	19.3	61.8	48.0	8.0	13.7	65.0	49.1	7.2	8.8					
E			59.9	45.1	10.5	23.3	59.4	45.7	8.5	16.8	57.1	41.8	9.0	12.8	29.88	28.53	(36.225)[1.147]		
			59.8	45.6	11.0	23.6	60.0	42.0	8.5	14.6	59.8	44.3	10.0	16.1	-	-	-		
			59.8	45.4	10.8	23.4	59.7	43.8	8.5	15.7	57.4	43.0	9.5	14.4					
F			61.8	48.8	10.0	22.9	60.8	47.4	8.5	17.0	59.2	43.9	9.0	16.8	28.00	27.33	32.82		
			61.5	48.2	10.0	25.6	61.6	48.4	9.0	18.5	60.5	45.5	9.0	18.9	-	-	-		
			61.6	48.5	10.0	24.2	61.2	47.9	8.8	17.8	59.8	44.7	9.0	17.8					
G			61.7	48.0	10.0	22.2	62.4	48.8	7.5	11.3	63.5	48.7	7.5	12.7	26.97	26.66	(35.097)[1.016]		
			61.8	48.6	10.5	24.0	59.3	46.9	7.5	13.5	63.3	49.0	8.5	16.8	-	-	-		
			61.8	48.3	10.2	23.1	60.8	47.8	7.5	12.4	63.4	48.8	8.0	14.8					

Notes:

(1) Forged to ~180" long. Forger HT dimensions ~10 1/2" t × 10 1/2" w × 39" l.
Cut 12" segment from 39" length from mid (180") length for MDAC destruct test.

(2) Stressed to 75% TYS.

(3) Standard = specimens from 2219-T851 plate 6 1/8" t exposed simultaneously.

* — Stress-strain curves available.

Legend:

( ) — K_Q values in parentheses

[ ] — R_{sc} values in brackets

1.5" wide specimens

Corrosion — 3 1/2% NaCl Alt. Imm.					
ransverse (℄ t and w: 1/4" D × 1" GL)					
lanks		Unstressed		Stressed(2)	
EL	RA	UTS	EL	UTS	EL
%	%	% Change in 30 Days			
9.0	15.4	-12.3	-84.2	-12.1	-73.7
9.5	14.5	-13.2	-78.9	-15.0	-78.9
10.0	17.4	-12.1	-78.9	-12.8	-78.9
9.5	15.7	-12.5	-81.0	-13.4	-76.8
6.5	9.4	-25.5	-91.2	-26.3	-82.4
5.5	8.6	-26.0	-91.2	-26.3	-100
5.0	6.4	-27.3	-100	-29.2	-100
5.7	8.1	-26.3	-94.7	-27.3	-94.7

TABLE 17. 2219-T852 RECTANGULAR HAND FORGING — SUMMARY COMBINED TESTS — ACTUATOR BRACKET — 14A30905

No. of Forgings	Test Loc.	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL %/4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL (%/4 D)	Long Transverse RA (%)	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL %/4 D	Short Transverse RA %
Forger Min. Gtd.		10 1/2	52	39	6	-	52	38	4	-	50	36	3	-
s* destruct W	$\bar{C}_L$	~10 1/2	(29) 56.5-63.8	43.5-49.6	9.3-11.4	-	(29) 55.7-63.2	43.2-50.2	5.0-10.0	-	(29) 56.3-63.8	42.0-48.4	5.7-9.3	-
5 ↓ M	↓	↓	(10) 58.7-63.2	44.3-46.8	10.0-12.5	17.0-27.7	(10) 56.0-63.3	42.0-49.2	5.0-9.0	7.8-18.5	(13) 56.7-65.5	41.8-49.8	6.0-10.0	5.1-18.9
s* total	$\bar{C}_L$	~10 1/2	(39) 56.5-63.81	43.5-49.6	9.3-12.5 (10)	17.0-27.7	(39) 55.7-63.3	42.0-50.2	5.0-10.0 (10)	7.8-18.5	(42) 56.3-65.5	41.8-49.8	5.7-10.0 (13)	5.1-18.9

W = Weber test, 0.357" D × 1.40" gage length tensile specimens
M = MDAC test, 1/2" D tensile spec. for properties, 1/4" D ST for stress corrosion
◯ = No. of specimens tested; min. to max. values obtained

*s mults representing 36 pcs 33" l

Forged dimensions — ~10 1/2" t × ~10 1/2" w × ~180" l
HT dimensions — ~10 1/2" t × ~10 1/2" w × ~33" l

TABLE 18. 2219-T852 CONTOUR AND RECTANGULAR HAND FORGINGS – CONDENSED SUMMARY COMBINED TESTS

P/N	No. of Forgings	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL %/4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL %/4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL %/4 D	Short Transverse RA %
14A30400 Gtd.		4	62	50	6	-	61	49	4	-	60	46	3	-
↓	55(1)	~7	(11) 63.4-66.4	50.7-53.3	10.0-13.0	-	(62) 62.4-69.0	49.0-54.8	4.5-10.0	4.4-9.8	(72) 61.4-68.4	47.9-54.0	4.0-9.0	(16) 6.0-10.5
↓	1(2)	↓	(3) 63.5-63.7	49.9-50.3	9.5-10.0	(3) 27.0-27.7	-	-	-	-	-	-	-	-
14A20084 Gtd.		4 1/2-5 3/4	61	49	6	-	61	48	4	-	59	45	3	-
↓	20(3)	~5 3/4	(58) 61.5-70.2	48.3-56.3	7.0-13.0	(18) 16.9-29.5	(78) 60.3-67.8	47.6-53.0	4.5-11.0	(18) 6.7-13.2	(79) 60.8-69.0	46.9-56.1	4.0-9.5	(24) 4.0-11.0
↓	1(2)	↓	(3) 59.4-59.7	45.0-45.4	8.0-8.5	(3) 21.2-23.0	-	-	-	-	-	-	-	-
14A30500 Gtd.		8	57	44	6	-	57	43	4	-	55	40	3	-
↓	61(4)	~8	-	-	-	-	(136) 57.1-68.1	43.1-53.8	5.7-10.0	(11) 9.0-15.3	(134) 57.3-67.5	41.2-52.7	3.6-10.0	(9) 9.3-21.5
↓	1(5)	↓	(19) 59.1-65.7	44.8-51.0	9.0-13.0	(16) 22.5-34.4	-	-	-	-	-	-	-	-
14A30400 Gtd.		8 3/4	55	43	6	-	55	42	4	-	53	40	3	-
↓	3(5)	~8 3/4	(3) 62.9-64.7	48.9-50.9	11.0-13.0	-	(3) 63.9-64.5	49.1-50.0	7.5-10.0	-	(12) 62.6-65.4	48.9-50.7	6.5-8.5	(9) 7.4-13.1
14A30905 Gtd.		11 1/2	52	39	6	-	52	38	4	-	50	36	3	-
↓	*(5) 8	~10 1/2	(39) 56.5-63.8	43.5-49.6	9.3-12.5	(10) 17.0-27.7	(38) 55.7-63.3	42.0-50.2	5.0-10.0	(10) 7.8-18.5	(42) 56.3-65.5	41.8-49.8	5.7-10.0	(13) 5.1-18.9
14A30400 Gtd.		10 1/2-12 1/4	52	39	6	-	52	38	4	-	50	36	3	-
↓	3(5)	~10 1/2	(3) 61.3-62.6	48.1-48.2	9.5-11.5	-	(3) 61.6-62.9	47.4-48.1	7.5-9.0	-	(12) 59.8-63.4	45.2-50.1	6.0-8.5	(9) 8.7-13.6
↓	3(5)	~12 1/4	(3) 59.1-60.6	45.7-47.1	11.0-12.0	-	(3) 58.4-60.4	44.3-46.7	6.0-8.5	-	(3) 58.2-61.6	46.0-49.2	7.5-9.0	-
↓	1(2)	↓	-	-	-	-	-	-	-	-	(3) 58.6-59.8	45.2-45.8	5.5-7.5	(3) 6.7-10.4

TABLE 18. (Concluded)

P/N	No. of Forgings	HT t in.	Longitudinal UTS ksi	Longitudinal TYS ksi	Longitudinal EL %/4 D	Longitudinal RA %	Long Transverse UTS ksi	Long Transverse TYS ksi	Long Transverse EL %/4 D	Long Transverse RA %	Short Transverse UTS ksi	Short Transverse TYS ksi	Short Transverse EL %/4 D	Short Transverse RA %
14A20084 Gtd.	7 1/2-14		50	37	6	-	50	36	4	-	48	34	3	-
	3(5)	~7 1/2	(9) 60.1-66.0	46.5-50.6	10.5-11.5	-	(9) 59.8-66.6	45.5-50.8	5.0-9.0	-	(9) 57.8-66.2	44.6-51.0	6.0-9.0	-
	3(5)	~12	(9) 57.6-68.9	44.9-56.3	7.0-9.5	(8) 8.2-18.0	(8) 58.1-64.3	45.0-52.7	4.0-7.0	(8) 3.6-10.1	(9) 58.0-69.0	46.3-56.6	4.5-7.0	(9) 5.1-10.9
	1(2)		-	-	-	-	-	-	-	-	(3) 53.9-54.7	41.7-43.0	7.5-8.0	(3) 10.2-12.7
14A20084 Gtd.		14	50	37	6	-	50	36	3	-	48	34	3	-
	3(5)	~14	(42) 55.6-66.7	43.2-51.8	8.5-11.5	(24) 13.9-24.3	(46) 50.0-70.6	42.4-54.7	2.5-8.5	-	(54) 54.1-64.3	42.3-51.0	4.0-8.0	(18) 5.5-12.8
	1(2)		(3) 55.3-56.3	42.9-43.6	10.5-11.0	(3) 27.5-28.5	-	-	-	-	-	-	-	-
14A30400 Gtd.		14-17	46	33	6	-	46	32	4	-	44	30	3	-
	3(5)	~14	(2) 57.6-58.3	45.0-45.5	10.0-11.5	-	(3) 55.9-58.5	42.0-50.4	8.0-11.0	-	(12) 55.7-60.3	41.5-48.1	6.5-9.0	(9) 10.9-13.2
	3(5)	~15 3/4	(12) 55.9-58.6	43.5-46.6	9.5-13.0	(9) 22.3-26.2	(12) 55.6-58.6	41.9-45.8	5.0-9.0	(9) 7.4-10.9	(12) 54.7-60.1	41.5-48.6	7.0-9.0	(9) 10.9-13.9
	55(1)	~16 1/4	(17) 55.5-61.3	43.2-48.2	9.5-13.5	(6) 21.9-26.4	(62) 54.1-68.4	41.4-53.5	4.5-9.0	(7) 4.7-10.6	(71) 53.8-66.0	41.3-54.1	5.0-9.5	(16) 9.4-14.7
	1(2)		-	-	-	-	(3) 55.8-57.8	42.6-45.3	5.5-7.5	(3) 7.8-15.0	-	-	-	-

(1) 3 destruct +52 forgings prolongation tests
(2) 1 destruct forging from MDAC aged 1/4 skirt
(3) 3 destruct +17 forgings prolongation tests
(4) 1 destruct +60 forgings
(5) Destruct forgings
◯ = No. of tensile specimens tested; min. to max. values obtained

*8 mults representing 36 pieces

TABLE 19. LARGE HAND FORGINGS — 2219-T852
PROPOSED MINIMUM GUARANTEED MECHANICAL PROPERTIES

	Forging & HT Thickness in.	Longitudinal (L)			Long Transverse (LT)			Short Transverse (ST)		
		UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %	UTS ksi	TYS ksi	EL %
1974-5	Up thru 4.0	62	50	6	62	49	4	60	46	3
↓	4-1/2	61	49	6	61	48	4	59	45	3
↓	8	57	44	6	57	43	4	55	40	3
1977	8-3/4	56	43	6	56	42	4	54	40	3
↓	11	54	42	6	54	41	4	53	39	3
↓	14	52	40	6	52	40	4	51	39	3
↓	17	50	39	6	50	40	4	50	38	3

REFERENCE

Davis, R. J.: Mechanical Properties of SRB Rolled-Ring Forgings and Large Hand Forgings. MDC G6791, May 1977. McDonnell Douglas Astronautics Company — West, Huntington Beach, California.

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APPENDIX A

MSFC PROCUREMENT SPECIFICATION FOR P/N 14A20084

3/17/75

MSFC PROCUREMENT SPECIFICATION FOR FORGING 14A20084

The forging drawing generated from this criteria must depict a forging of sufficient size to manufacture the detail part no. 14A20083 plus provision for taking test samples on deliverable items. A concept of such a forging is shown on an attached sketch.

1. Material: 2219-T352 Al alloy forging per QQ-A-367H.

2. Metal stamp identification number per AMS 2808A.

3. Ultrasonic inspect per MIL-I-8950B Class A, where thickness is 6 inches or less and Class B where thickness is greater than 6 inches.

4. Heat treat, quench, and stress relieve by compression, the entire forging to -T352 temper per MIL-H-6088E.

5. For forging serial no.'s 1, 5, and 12: Age to -T852 temper per MIL-H-6088E (350°F ± 10°F for 18 hours) and destructively test. Test specimens shall be taken in locations shown on the attached sketch. Provide results of macroscopic examination and tensile tests to procuring agency within 10 days of tests.

   a. Document grain flow pattern and note grain size on 1/4 inch (min.) slices at the six locations shown on sketch.

   b. Test all tension specimens per Fed. Std. 151. Test specimens shall be types R1 & R3. Preferred specimen size is in the order stated.

   c. Provide the five segments noted on sketch to procuring agency at the same time test results are provided. Each segment shall be clearly identified by part number, location on part, serial number, and lot number. Ship to: MSFC, Huntsville, AL, CPB21, Attn: M. W. Brennecke

6. The minimum required individual mechanical properties for this forging in each of the two indicated thicknesses (-T852) are:

Thickness	I		II		Elongation all thicknesses
Direction	FTU KSI	FTY KSI	FTU KSI	FTY KSI	EL% 2"/4D
Longitudinal	61	49	50	37	6
Long Trans.	61	48	50	36	4
Short Trans.	59	45	48	34	3

7. Deliverable Forgings

   a. Establish properties on a single forging from each forging lot* using the designated 1/2 width test pieces cut from each end of the -T352 forging, aged to -T852 and sectioned for designated specimens in locations shown on attached sketch. Leave the remaining 1/2 width test piece intact as an integral part of the -T352 forging.

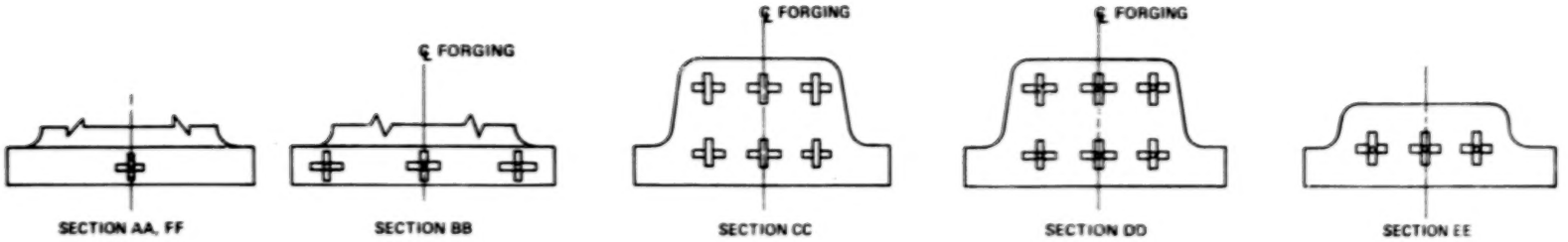
   b. Document grain flow pattern and note grain size on above 1/2 width slices and report data to the procuring agency.

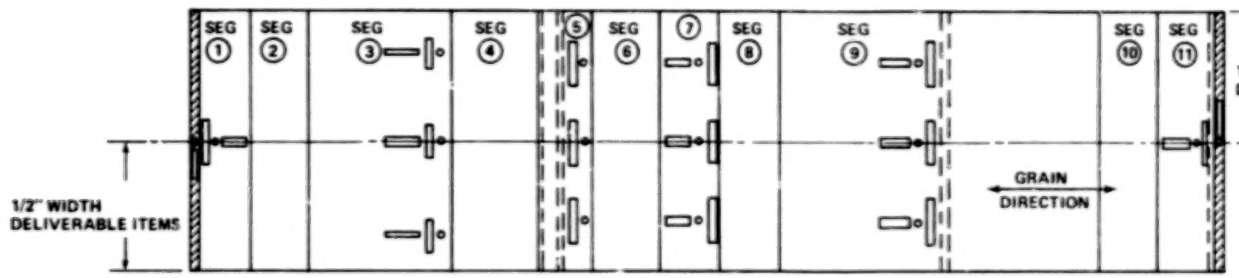
   c. Determine tensile properties in long transverse and short transverse directions and report to procuring agency. Specimens and test per note 5 (b).

   d. The remaining forgings from each lot will be delivered with the designated end strips as an integral part of each forging.

8. Each individual forging shall be serialized for record traceability.

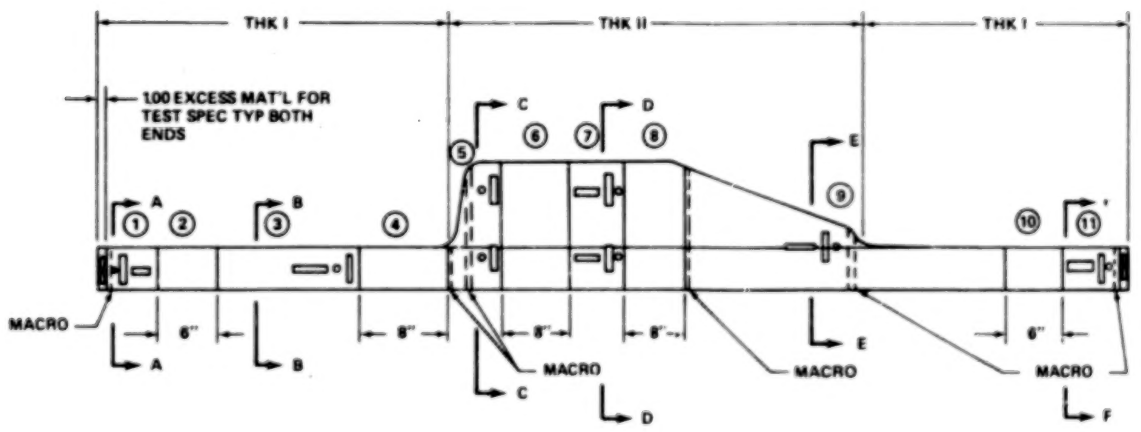
* A lot shall consist of not more than 6,000 pounds of forging heat treated as one furnace charge.





NOTES:

1. SEGMENTS 2, 4, 6, 8, AND 10 OF THE TEST FORGINGS ARE TO BE SHIPPED TO MSFC IN THE T852 TEMPER.
2. LAYOUT OF TEST SPECIMEN LOCATIONS SHOWN ON THIS FORGING CONCEPT SKETCH IS SUBJECT TO REVIEW FOR PRECISE LOCATION OF SPECIMENS BASED ON THE FORGING DRAWING GENERATED BY THE FORGER.



CONCEPT FORGING
SKETCH 14A20084

APPENDIX B

ALCOA FORGING CERTIFICATION FOR P/N 14A20084

CERTIFIED INSPECTION REPORT AND TEST RESULTS — **WROUGHT PRODUCTS**

ALUMINUM COMPANY OF AMERICA

PITTSBURGH PA.

SHIPPED FROM
CLEVELAND, OHIO

CODE NUMBER 042-916808 ALCOA NUMBER ATB 41220 X

INVOICE TO
FINANCIAL MANAGEMENT OFFICE
GEO. C MARSHALL SPACE FLIGHT CTR NASA
MARSHALL SPACE FLIGHT CENTER
ALABAMA 35812

INVOICE NO. 21710839
INVOICE DATE 12/05/75
GROSS WEIGHT 711[illegible]
B/L NO. 10840
DATE SHIPPED 12/05/75
VIA MID-WEST GROWERS CO-OP
F.O.B. DESTINATION

SHIP TO
MCDONNELL DOUGLAS ASTRONAUTICS CO.
7391 HEIL AVE. HUNTINGTON BEACH, CA.
ATTN J.B.HEISER 92647 04-059
MARK FOR M/F A03-1558-GFM CONTRACT
HAS 8-31614 DCN 2-5-06-54901-01

CUSTOMER P.O. NO. NAS8-31608
GOVT. CONTRACT NO.

AUTHORIZED SIGNATURE(S) [signature] Quality Assurance Manager

[redacted]

ALCOA *products as follows*
HAND FORGINGS FED SPEC
QQA-367H, MIL-H-6088E, MIL-I-8950B
CLASS A IN AREAS LESS 6 IN. THICK,
CLASS B AREAS OVER 6 IN. TK AMS2808A

ALCOA NUMBER ATB 41220 X
ALLOY AND TEMPER 2219-T352

ITEM NO.	ITEM DESCRIPTION	ACCT. CODE	QUANTITY SHIPPED PCS., FT., ETC.	QUANTITY SHIPPED POUNDS
001	FORWARD SKIRT ACOA DWG 750415NB NASA SPEC 14A20084 NASA DWG 14A 20083-1	4633	2	6976
	TOTAL FOR INVOICE			6976

A FOLLOWING MIN. PROPERTIES TO APPLY

	AREA I			AREA II	
	TS	YS	EL	TS	YS	EL
LONGITUDINAL	61	49	6	50	37	6
LONG TRANS	61	48	4	50	36	4
SHORT TRANS	59	45	3	48	34	3

PROPS FOR FORGINHS AGED TO T852 TEMPER
DEST TEST S/N S 1,~~512~~ PER CUST B/P

SHIPMENT SUMMARY

ITEM NO.	TOTAL SHIPPED TO DATE PCS., FT., ETC.	TOTAL SHIPPED TO DATE POUNDS	PART. OR COMPLETE	PACKAGES	LOT NUMBERS
001	2	6976	C	2 PALLETS	LOT S/N 5059510 - 10 5059509 - 9

PP = PARTIAL, C = COMPLETE, PP = PRIOR PARTIAL, O = NO SHIPMENTS, L = OVERSHIPMENT

SF 4023-1 REV. 3-60

PITTSBURGH © REX & HOWELL CO. 8

T E S T R E S U L T D A T A

A L C O A C L E V E L A N D W O R K S

TOOL 701176
PACK-NO 650070 605134
INVOICE 21710039 ORDER ATH412204 001 2 PIECES 1976 POUNDS

SEE REF NOTE	LOT NUMBER	SERIAL NUMBERS	TENSL STRTH KSI	YIELD STRTH KSI	ELONG PCT IN.	BHN
	5059519	9				
20	1-1L		66.4	52.3	11.5	124
20	1-LT		65.7	51.5	8.5	130
20	1-ST		65.6	51.2	9.5	124
20	//-1L		66.4	56.3	12.0	124
20	//-LT		65.7	50.3	9.0	130
20	//-ST		65.8	51.8	8.0	124
	5059510	10				
20	1-1T		67.2	52.5	7.0	124
20	1-ST		67.2	52.2	7.0	130
20	//-LT		66.7	52.7	7.0	124
20	//-ST		66.3	52.0	7.0	130

ALLOY 2219 CHEMICAL COMPOSITION

	CU	FE	SI	MN	MG	ZN	TI	ZR	V	OTHER
MAX	6.8	.30	.20	.40	.02	.10	.10	.25	.15	EACH .05
MIN	5.8	.0	.0	.20	.0	.0	.02	.10	.05	TOTL .15

20 CUT FROM A FORGING OR PROLONGATION FROM THE INDICATED LOT AND FURTHER PROCESSED FROM THE ORDERED TEMPER TO THE T852 TEMPER.

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APPENDIX C

MICROSTRUCTURE OF CORRODED SPECIMENS

APPENDIX C - MICROSTRUCTURE OF CORRODED SPECIMENS

Selected corroded specimens from samples of each of the forgings reported in Tables 4, 9, 13 and 16 were examined metallographically to determine grain structures and type and depth of attack. The identification of these specimens is shown in Table 1 and representative microstructures are presented in Figures 1-4.

There is a greater difference between the relative grain structure of the 10-1/2" thick rectangular forging (Figure 1a) having a 110 sq. in. cross sectional area vs. a contour forging at the same thickness (Figure 1b) but having about double the cross section area, 236 sq. in., than between the two rectangular forgings having different thicknesses of 10-1/2" (Figure 1a) and 8" (Figure 2b) and cross sectional areas of 110 and 88 sq. in., respectively.

Likewise there is greater difference between the relative grain structure of the 6-1/8" thick rolled plate (Figure 3a) vs. a contour forging at 5-3/4" thickness (Figure 3b) having a corresponding cross sectional area of approximately 170 sq. in. than between the structures of this contour forging at 5-3/4" t vs. another at 8-3/4" thickness (Figure 4a) having a corresponding cross sectional area of approximately 196 sq. in.

These observations clearly demonstrate that not only thickness but also total cross sectional area are important factors relating to forging parameters, heating and quenching rates that strongly influence resultant structure and properties in 2219-T852 forgings.

Regardless of thickness and cross sectional area, with their associated interdependent processing variations, all specimens examined showed only pitting type of attack with no evidence of intergranular attack even at 400X magnification as illustrated in Figures 2, 3 and 4 for 2219-T852 large hand forgings up to 15-3/4" thick and 413 sq. in. cross sectional area heat treated and aged by the forger.

APPENDIX C

TABLE I

IDENTIFICATION OF STRESS CORROSION SPECIMENS FROM LARGE HAND FORGINGS

SRB Location of Forging	Part No.	HT wt/lbs	Forging S/N	Forging Seg.	Forging Thick	Forging Area/in^2	Spec. No.	Stress ksi †	Forger Type Prod.	Plate Thick	Spec. No.	Stress ksi †	Fabricator
2219-T852 Al Hand Forgings - Contour & Rectangular										2219-T851 Al Reference Plate			
Fwd Skirt Thrust Post	14A20084	3500	1	2	5-3/4"	170	507*	37.8 b.	Alcoa, Contour	6-1/8"	R8	37.0 b.	Alcoa
	↓	↓	↓				508	↓		↓	R13*	↓ a.	↓
				8	14"	413	516	33.0 ↓	↓				
Aft Skirt	14A30500	1100	1	6	8"	88	589	33.1 c.	Weber, Rectangular				
Actuator Bracket	14A30905	450	B	4	10-1/2"	110	598	31.8 d.	↓				
Hold Down Post	14A30400	3000	1	4	8-3/4"	196	544	36.7 a.	Alcoa, Contour				
	↓	↓	↓	6	10-1/2"	236	552	34.2					
				8	12-1/4"	276	560	—	↓				
							563	33.5					
				10	14"	315	571	32.7					
				12	15-3/4"	354	581	32.3 ↓					

† 75% of TYS of Adjacent Blanks For % loss in strength after exposure:

a. See Table 4, p 42 & 43

b. See Table 9, p 54 & 55

c. See Table 13, p 65

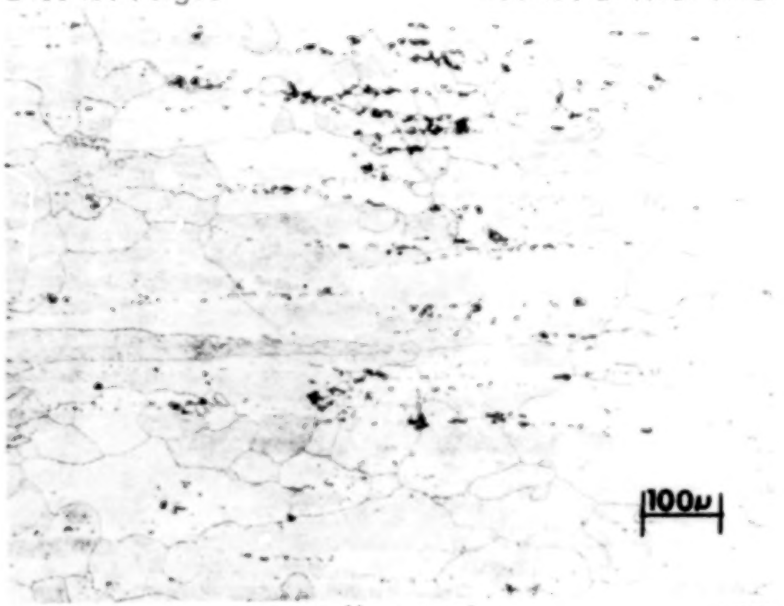
d. See Table 16, p 70

* Failed in handling during removal from fixture.

All Specimens are 1/4"D ST direction from ℄ t & w

ACTUATOR BRACKET P/N 14A30905 S/N B
Seg 4, 10-1/2"t x 10-1/2"w x 180"l -- #598
Rectangular Forging 2219-T852

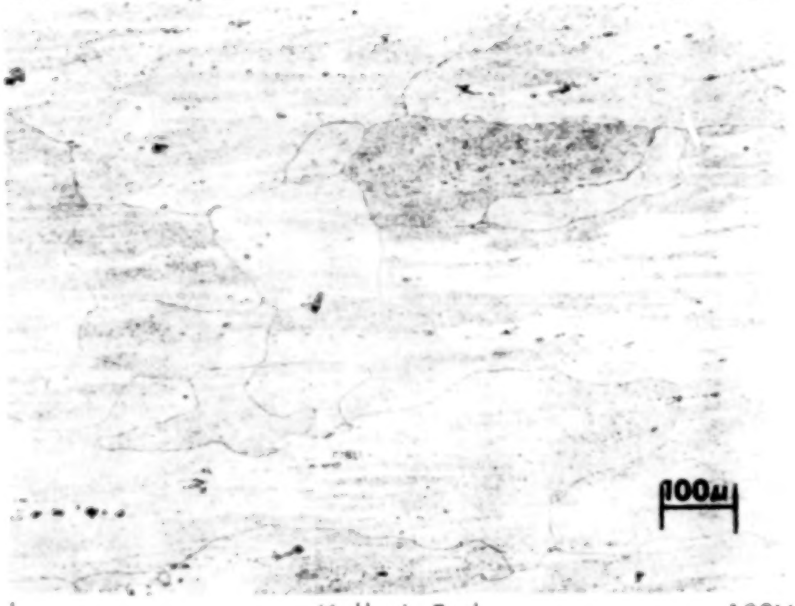
2400 lb. Forged 450 lb. at Heat Treat



a. Keller's Etch 100X

HOLD DOWN POST P/N 14A30400 S/N 1
Seg 6, 10-1/2"t x 22-1/2"w x 100"l -- #552
Contour Forging 2219-T852

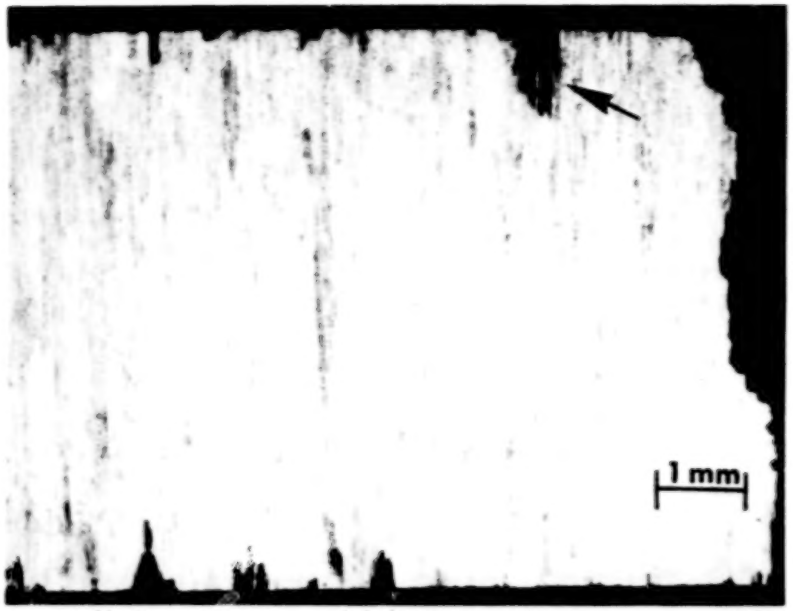
3000 lb. Forged 3000 lb. Heat Treat



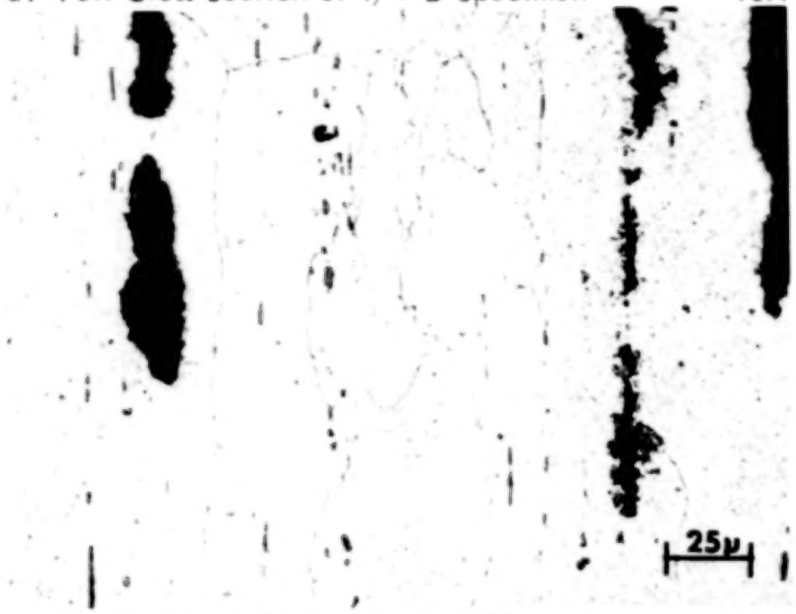
b. Keller's Etch 100X

Note that the difference in grain structure at the ℄ t and w of the two different products reflect the greater amount of work inherent with the smaller cross section of the rectangular forging vs. the more massive contour forging.

FIGURE 1 - Microstructure of 2219-T852 Rectangular vs. Contour Forging at 10-1/2" Thickness



a. Full Cross Section of 1/4"D Specimen 10X



c. Bottom End of Typical Surface Pit 400X

b. ST Direction 50X

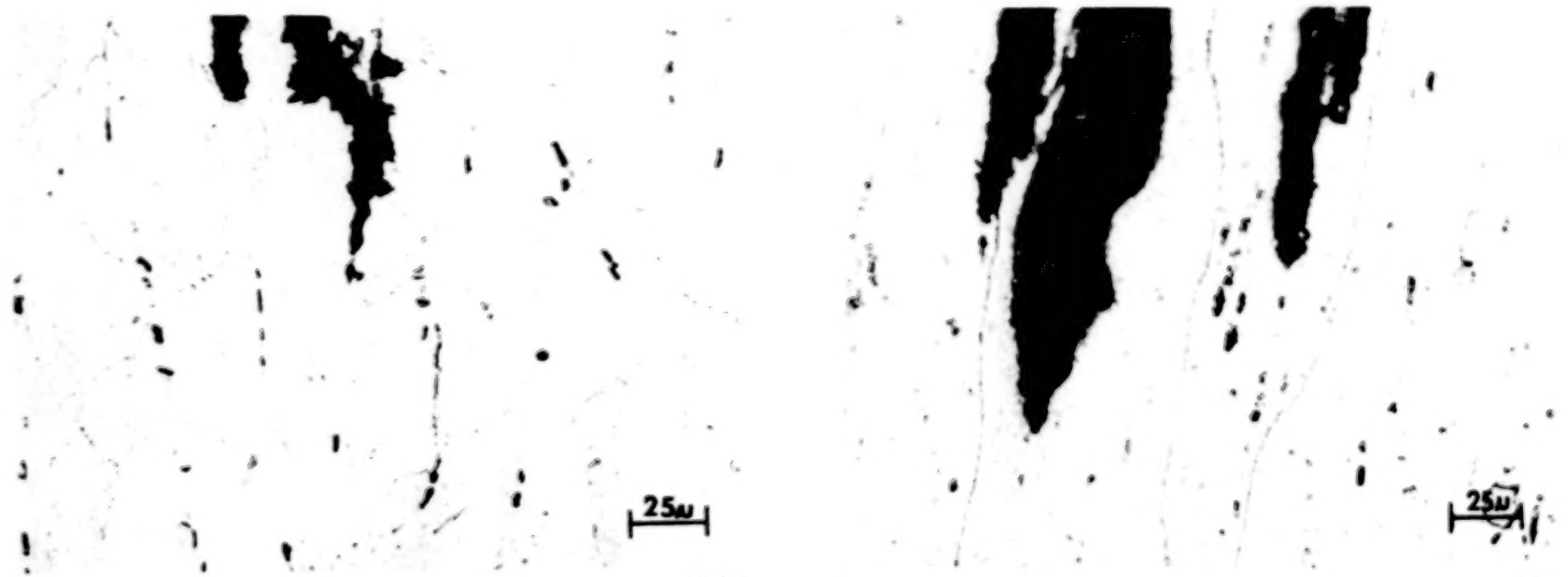
Rectangular Hand Forging P/N 14A30500 S/N 1
8"t x 11"w x 110"l, Seg. 6 -- #589, 33.1 ksi Stress
1100 lb. Forged and Heat Treated 2219-T852
Longitudinal Cross Section of Short Transverse (ST)
Stress Corrosion tensile specimen after exposure to
3.5% NaCl solution by alternate immersion for
30 days stressed to 75% of the TYS (℄ t & w).
Note only pitting type of attack with no evidence of
intergranular attack - Keller's etch
(cf Table 13, p65 for % loss in strength)

Appendix C

FIGURE 2 - Microstructure and Corrosion Attack of 2219-T852 Rectangular Forging

ROLLED PLATE
6-1/8" t -- #R8, 37.0 ksi Stress
Reference Material 2219-T851

THRUST POST P/N 14A20084 S/N 1
Seg 2, 5-3/4" t x 29-1/2" w x 115" l -- #508, 37.8 ksi Stress
Contour Forging 2219-T852



a. 400X b. 400X

Longitudinal cross sections of short transverse (ST) stress corrosion tensile specimens after exposure to 3.5% NaCl solution by alternate immersion for 30 days stressed to 75% of the TYS (℄ t & w).
Note differences in grain structure between the rolled and the forged product in a similar thickness area.
Only pitting type of attack was observed with no evidence of intergranular attack on either product (Keller's etch).

FIGURE 3 - Microstructure and Corrosion Attack of 2219-T851 Rolled Plate vs. -T852 Contour Forging at ~6" Thickness

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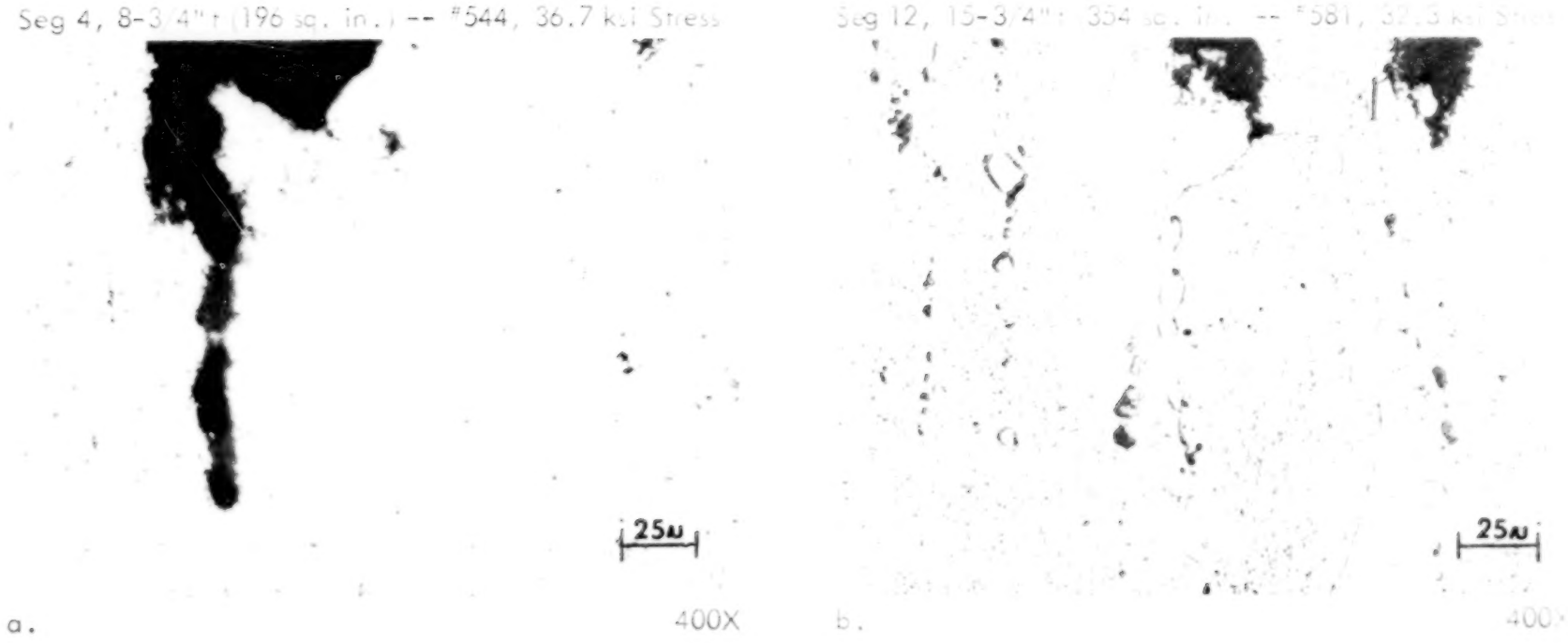
HOLD DOWN POST P/N 14A30400 S/N 1
7-16-1/4" t x 22-1/2" w x 100" l
Contour Forging 2219-T852



Note difference in grain structure for this hold down post at 2 different thickness locations,
a. 8-3/4" t near the forward position of the post and b. 15-3/4" t near the aft portion of the 100" length.
Only pitting type of attack was observed with no evidence of intergranular attack even in the most massive area having the least working and the slowest quench (Keller's etch) — Same exposure as Fig. 2 & 3.

FIGURE 4 - Microstructure and Corrosion Attack of 2219-T852 Contour Forging at 8-3/4 and 15-3/4" Thickness

Appendix C

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TP-1383		

4. TITLE AND SUBTITLE	5. REPORT DATE
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15. SUPPLEMENTARY NOTES

Prepared by Materials and Processes Laboratory, Science and Engineering

16. ABSTRACT

This report presents the mechanical properties, including fracture toughness, and stress corrosion properties of four types of 2219-T852 aluminum alloy hand forgings. Weight of the forgings varied between 450 and 3500 lb at the time of heat treatment and dimensions exceeded the maximum covered in existing specifications. Dimensions ranged from approximately 5-3/4 to approximately 16-1/4" thick, 10-1/2 to 29-1/2" wide and 33 to 115-1/2" long at heat treatment. The forgings were destructively tested to develop reliable mechanical property data to replace estimates employed in the design of the Space Shuttle Solid Rocket Booster (SRB) and to establish minimum guaranteed properties for structural refinement and for entry into specification revisions. The report summarizes data required from the forgers and from the SRB Structures contractor. Specific technical requirements for testing were defined; testing was coordinated; and results were organized, analyzed and evaluated by the Materials and Processes Laboratory of the George C. Marshall Space Flight Center.

17. KEY WORDS		18. DISTRIBUTION STATEMENT
Al alloy	Mechanical properties	STAR Category: 26
2219-T-352, -852	UTS, TYS, EL, RA	
Large hand forgings	Fracture toughness	
Rectangular forgings	Stress Corrosion	
Contour forgings	Ambient, 200 & 300^{0}F	
Macrostructure	Stress/Strain curves	

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
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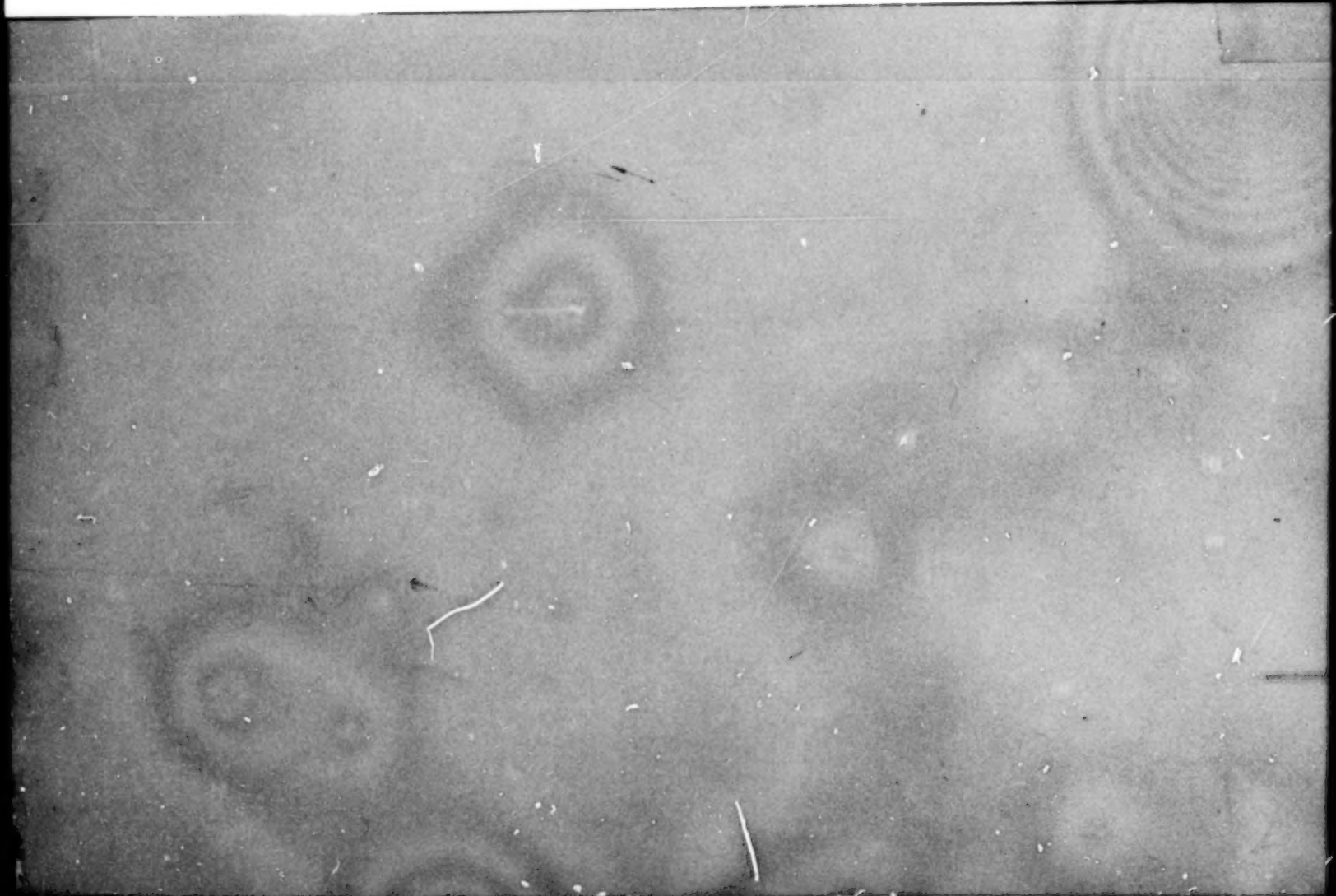

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